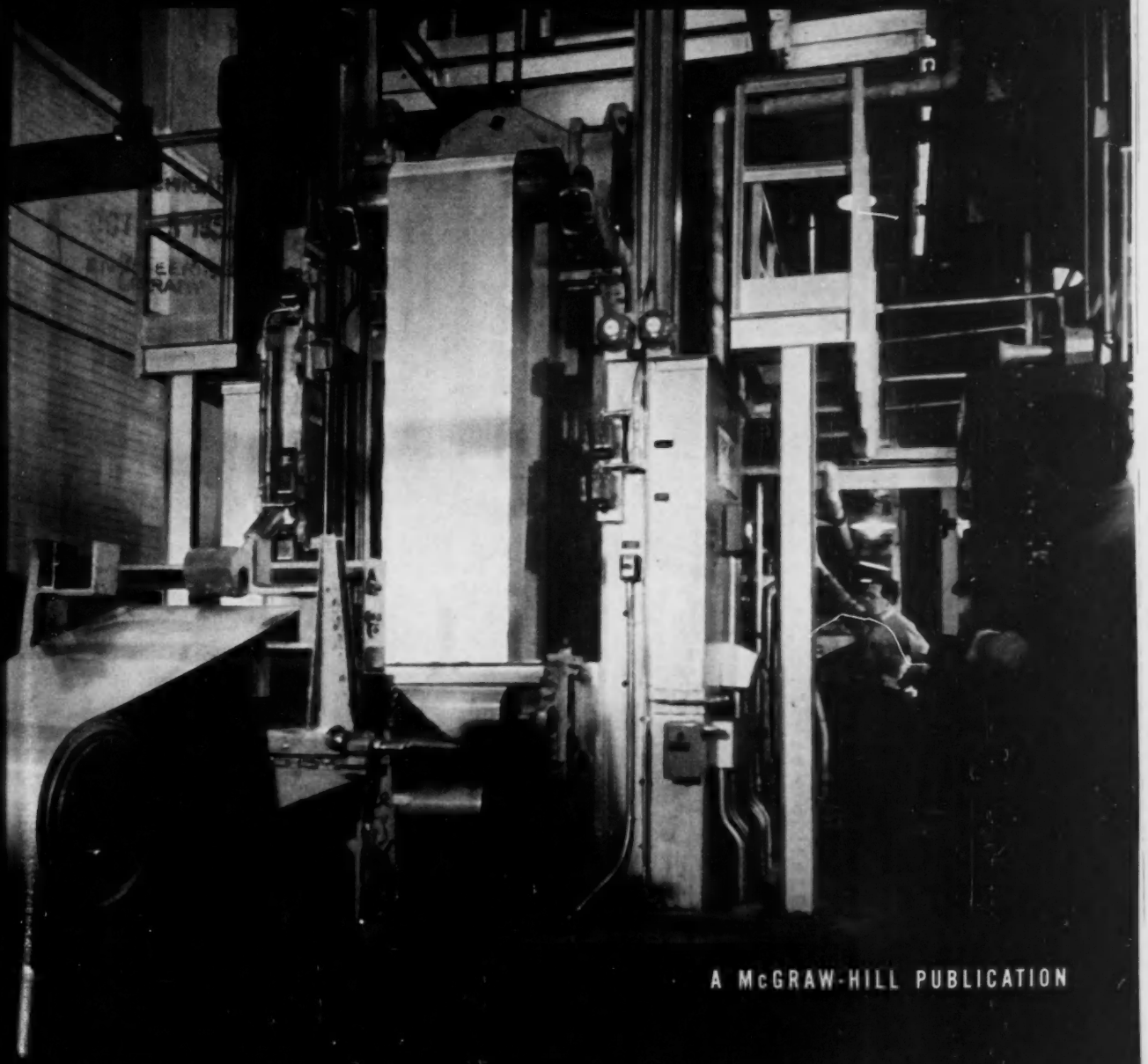
Product Engineering

OCTOBER 1952

Shell Molding • Radioisotope Applications
Potentiometer Characteristics
Trends in Plastics • Hydraulic Accumulator Circuits
Corrosion Factors in Design
Analysis of Control Rods
Locking Threaded Fasteners



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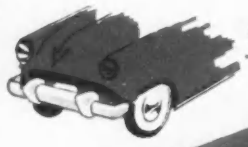
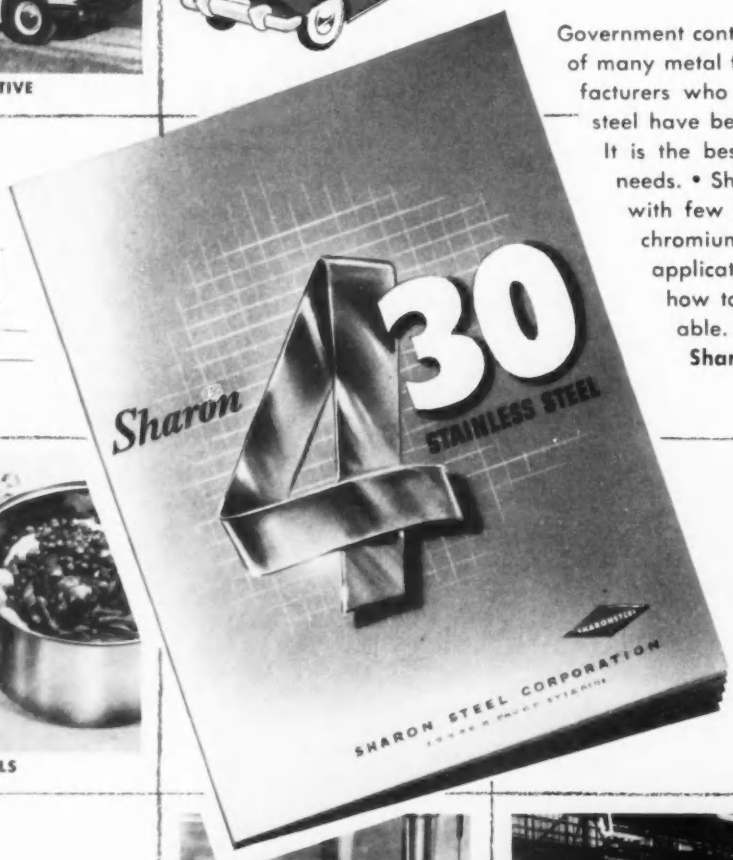
How

facts about 430 Stainless Steel for manufacturers concerned about critical materials

AUTOMOTIVE





Government controls are pinching the raw material supplies of many metal fabricators. However, many of these manufacturers who are familiar with Sharon "430" stainless steel have been able to quickly adapt it to their needs. It is the best available material for many of today's needs. • Sharon "430" is in good supply and available with few restrictions as to end use. It is a straight chromium stainless steel with hundreds of successful applications. A new booklet with instructions on how to fabricate Sharon "430" stainless is available. Get your copy by writing department 7105

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UTENSILS

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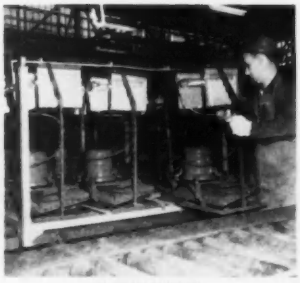

APPLIANCES

ARCHITECTURAL

Sharon 430 stainless steel

SHARONSTEEL

VOLUME 23

PRODUCT ENGINEERING

NUMBER 10

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OCTOBER, 1952 PRODUCT ENGINEERING Vol. 23, No. 10

Published monthly by McGraw-Hill Publishing Company, Inc., James H. McGraw (1860-1948), Founder. **Publication Office, 99-129 North Broadway, Albany 1, N. Y.**

Executive, Editorial and Advertising Offices: McGraw-Hill Building, 330 W. 42nd St., New York 36, N. Y. Curtis W. McGraw, President; Willard Chevalier, Executive Vice-President; Joseph A. Gerardi, Vice President and Treasurer; John J. Cooke, Secretary; Paul Montgomery, Senior Vice-President, Publications Division; Ralph B. Smith, Vice-President, Editorial Director; Nelson Bond, Vice-President, Director of Advertising; J. E. Blackburn, Jr., Vice-President, Circulation.

Subscriptions: Product Engineering—Subscription Service, 99-129 N. Broadway, Albany 1, N. Y., or 330 W. 42nd St., New York 36, N. Y. Allow one month for change of address.

Subscriptions are solicited only from executives, engineers and consultants engaged in the design of machinery and other engineered products. Position and company connection must be indicated on subscription orders.

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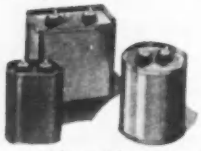

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Highlights

When requesting further information from companies and organizations mentioned in the items below, confusion can be avoided by refering to the issue of Product Engineering in which items appear

NONMETALLIC MATERIALS

PATTERNED PERFORATIONS feature a line of different colored sheet materials that are comparable to laminated plastics or vulcanized fiber. Fiberok, made by Pearson Industries, Chicago 40, Ill., is easily cut and fastened to form decorative parts on electrical products such as radios.

GOLD-COLORED silicone base paint with high heat resistance is announced by Speco, Inc., Cleveland 9, Ohio. Heat-Rem XG-170 Gold is made of copper flakes in a silicone base and will withstand temperatures to 1,700 F. Because of the copper, the paint is said to prevent rust and resist corrosion from mild acids, alkalies and industrial fumes. Upon heating, it fuses with the base metal, forming a solid copper coating that contracts and expands with temperature.

AIRPLANES OF THE FUTURE could have "glass" wings, ailerons, stabilizers and fuselages, says one spokesman for Northrop Aircraft, and these surfaces might be attached to titanium structural members with "glass" rivets. The "glass" is, of course, reinforced plastics -- glass fiber and one or more of the many resins, such as the polyesters, phenolics, epoxys, silicones and melamines. These may answer the problem: How to conquer the "heat barrier" to ultrasonic flight?

EFFECTIVE LABORATORY USE of ceramic coatings to prevent rapid oxidation of molybdenum and the absorption of carbon by stainless steels was recently announced by the National Bureau of Standards. Various chromium and glass (frit) coatings were bonded to specimens of molybdenum, then submitted to oxidation tests under tension at 1,500 to 1,800 F and to flame tests in the region from 2,000 to 3,000 F. In the lower temperature range, specimens stood up under load for 1,000 to 3,000 hr. At 2,800 F, with no applied load, it was possible to achieve protection for as long as seven hours.

CORK-BASE GASKET MATERIAL withstands flange loads up to 100,000 psi without damage, according to Armstrong Cork Co. of Lancaster, Pa. In lightweight constructions, Accopac conforms to normal irregularities without distorting flanges between bolts. On rough, heavy flange surfaces, it fills ordinary imperfections to provide a tight, dependable seal. Cork is coated with rubber to insure dimensional stability.

A SYNTHETIC FIBER that withstands temperatures to 2,300 F is a recent development of the Carborundum Co., Niagara Falls, N. Y. Made from aluminum oxide and silica that is fused and then converted to a fluffy white mass by a stream of air, Fiberfrax can be processed and combined with various materials to form insulation, filter paper, wicking and other useful products.

TEFLON-GLASS CLOTH laminated with copper foil on one or both sides has been designed for printed circuit use by the United States Gasket Co. of Camden, N.J. Electrical and mechanical properties remain constant from -65 to +200 F. The material withstands mechanical and thermal shock, will not carbonize and is non-flammable.

METALLIC MATERIALS

PLATED RHODIUM has been the subject of extensive studies at Bendix Aviation Corp. The hard platinum colored metal is highly corrosion resistant, melts at about 3,600 F and has fair electrical conductivity. Combinations of these properties suggest uses in jet and rocket propulsion, instruments and electrical contacts.

GOOD FLUIDITY AND WETTING PROPERTIES mark Westinghouse's Phos-Silver alloy as promising for use in brazing copper, brass and bronze. On heavy sections that absorb a lot of heat, its low brazing temperature (1,225 to 1,275 F) reduces brazing time. On fine work or low melting brass, where there is danger of over-heating, it provides an extra margin of safety.

(continued on page 7)

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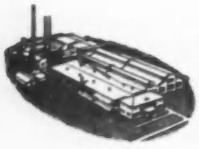
LET US FIGURE YOUR MOULDED THERMOSETTING JOB

Those are our two specialties. *Thermosetting mouldings* of all kinds—including Teflon and glass-filled polyesters. *Action—fast action*—on engineering, design, mould-making, moulding and finishing. Any or all of 'em!

Your plastics moulder can only offer you two things—equipment and the ability to use it. We've been building, adding to, and modernizing our store of both for over 35 years now. And we're ready for your job right now. Write or phone our main office or your closest branch office.



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FOR OVER 36 YEARS PLANNERS AND MOULDERS IN PLASTICS

HIGH-PURITY MERCURY is now processed and marketed specifically for use in instruments. An unbreakable 5-lb polyethylene bottle with flexible dispensing tip delivers the mercury directly to the instrument from a dustproof chamber. Bethlehem Apparatus Co. of Hellertown, Pa. recommends its use in manometers, thermometers, cathode cells, meters and gages of all types.

A SUBSTITUTE for cobalt- and columbium-bearing alloys is Haynes Stellite Co's Hastelloy X.

Composed of 22.0 percent Cr, 45.0 percent Ni, 9.0 percent Mo, 0.15 (max) percent C, plus Fe, new alloy has good heat and oxidation resistance, is superior to Multimet in formability.

DEVELOPED ESPECIALLY for applications that call for anodic finishes, Alcoa's new C57S non-heat treatable aluminum alloy contains 1.0 percent magnesium and 0.3 percent manganese. With mechanical properties intermediate between those of 2S and B50S, material may replace 52S in some instances, thus eliminating the yellowish tinge characteristic of the latter alloy.

COMPONENTS

"HOT SANDWICHES" of aluminum, copper, silver and plastic built into aircraft are solving

icing problems on 650-mph jet planes, according to Lockheed researchers. "Hot" because they are electrically heated, these sandwiches are new de-icing boots designed for use on wing and tail leading edges in place of rubber anti-ice equipment. Advantages are aerodynamically clean construction, quick response to heating current, uniform surface heat distribution.

VERY-HIGH-FREQUENCY TRANSISTORS have been developed by Radio Corporation of America. Frequencies as high as 225 megacycles are reported, giving promise of applications in television, FM radio and point-to-point radio communication. Spacing of contact points and resistivity of the crystal determine response.

A BRAKE DRUM made of welded steel and copper is said to last seven times as long as conventional cast-iron types. Copperweld Steel Co., Glassport, Pa., claims the combined metals quickly dissipate friction heat that burns surfaces of ordinary cast iron drums and linings. The drum is being introduced on heavy trucks and buses.

WORD FROM GERMANY is that aluminum can be substituted for the copper windings of medium and large size transformers with only a slight increase in the amount of steel required. New winding system has greater resistance to short circuiting, is less susceptible to damage and has better heat dissipation. On a 20 mva 110 kv series transformer, 1,970 kg of aluminum were substituted for 5,100 kg of copper. This resulted in an increase of steel from 14,000 to 16,000 kilograms.

PLUG-IN THERMOSTATS with time controls are a recent development at Connecto-Stat, West Hempstead, N.Y. Air-conditioning units or portable electric heaters can be plugged into the relay unit, which will maintain an even temperature by starting or stopping the appliance.

CONSTANT LEVEL DEVICE designed at the Bureau of Standards for liquids has a vertical tube with inlet and outlet connections near the top. Just below the outlet, this tube is sealed off except for a small open tube that extends be-

low this point, connecting the upper and lower sections of the larger tube. An open cup of mercury is supported below the small tube by a float which rises and falls with the liquid. When the liquid level rises, float raises the mercury cup to seal off the lower end of the small connecting tube; when the level drops, float and mercury cup descend, allowing liquid to pass.

PROCESSES

IN AN EFFORT to capitalize on molybdenum's 4,750-F melting point and high thermal conductivity (seven times that of austenitic stainless), Curtiss-Wright is studying methods of welding the various alloys. Results so far show fabrication is successful using helium-shielded tungsten electrodes. If stresses are not excessive, these alloys can be used at 3,000 Fahrenheit.

WEIGHT REDUCTIONS that mean a 150-mile increase in operating range are the result of using

titanium in airframe parts. North American Aviation is substituting commercially pure RC-70 and RC-130A alloy for stainless in aft fuselage webs, channels, frames and angles where operating temperatures do not exceed 800 F. Preheating of blanks to 800 - 1,000 F is necessary.

(continued on page 9)

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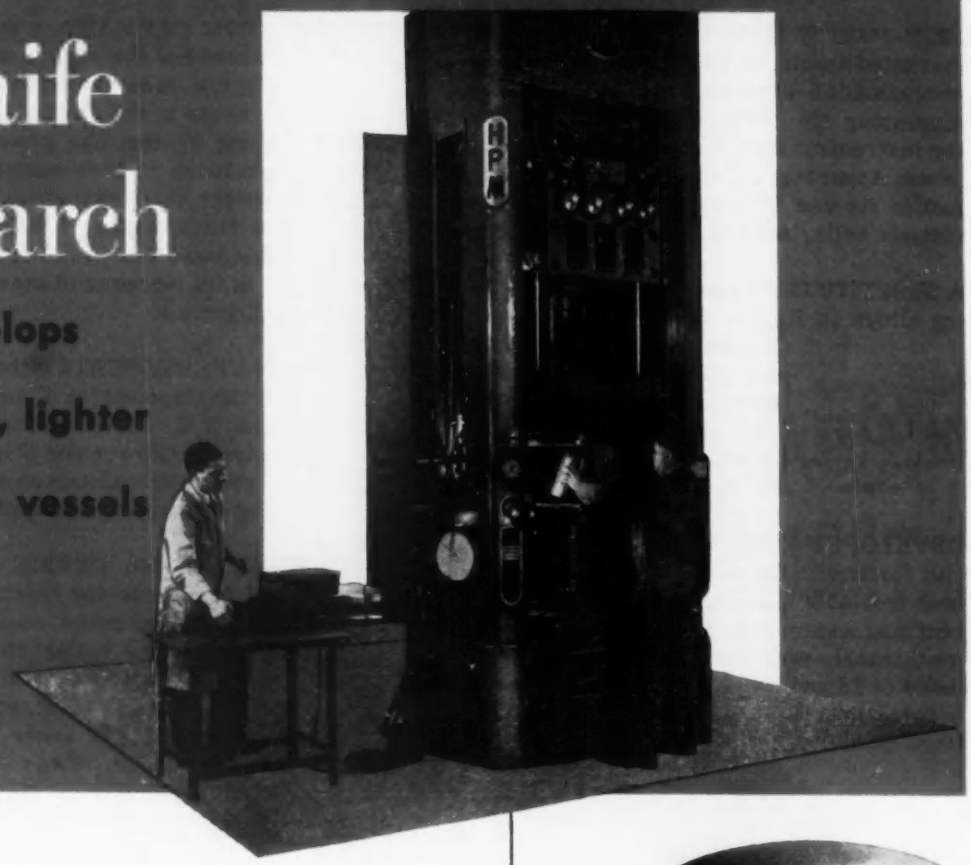
Scaife research

develops stronger, lighter pressure vessels



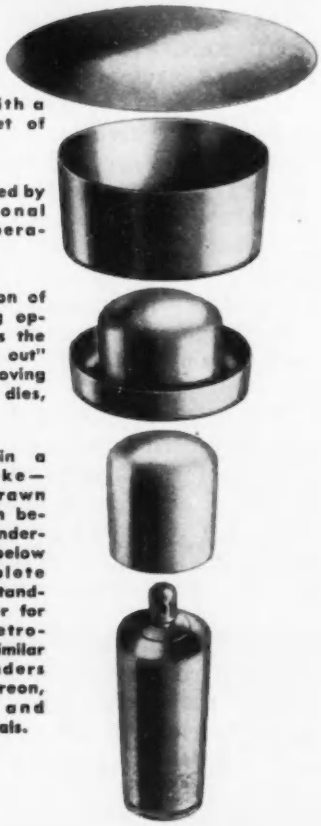
The pressure vessels and deep-drawn shapes being made today in the Scaife factory are *better* because of scientific research in Scaife Laboratories. For example, the development of the new Scaife Dura-Lite LP-Gas Cylinder included a complete study of the deep-drawing process, using half-size parts made on the research department press shown above. This procedure, supplemented by complete metallurgical, physical, chemical and specialized studies, permits accurate evaluation of various materials, drawing methods and processing procedure. The result is a better, more serviceable product designed and made on sound engineering principles.

SCAIFE COMPANY

OAKMONT (Pittsburgh District), PENNA.

Makers of Pressure Vessels for Air, Gases and Liquids

Here is the "big brother" of the press shown at the top of the page. Full-size cylinder-half has been formed in one stroke of the press (see right) and is being removed for processing and assembly.



Starting with a circular sheet of steel—

a cup is formed by a conventional drawing operation.

A continuation of this pressing operation turns the cup "inside out" without removing it from the dies,

completing—in a single stroke—the deep-drawn shape, which becomes a cylinder-half. Shown below is the complete cylinder, a standard container for liquefied petroleum gas. Similar Scaife cylinders are used for freon, acetylene and other materials.

SOFT SOLDERING of sheet aluminum and magnesium directly with 50-50 tin-lead, using no flux and no special cleaning or abrading preparation, is reported by Hubeny Bros, Roselle, N.J.

THE SUITABILITY of new machining and grinding methods for use in finishing tough alloys used in jet engines is discussed in report MAB-18-M

issued by the Metallurgical Advisory Board in Washington, D.C. Methods reviewed cover electrolytic, electro-sparking and ultrasonic techniques. Ultrasonics can be used on both metals and nonmetals because the process does not utilize electric current directly. Commercial use must be on an extensive scale to effect any savings.

FORTY YEARS AGO the four flat surfaces of an automobile cylinder head were machined at a rate which required 162 machine tools to produce 108 pieces per hour. Five years ago, improved machines and cutting tools had advanced this job so that the same output was produced by six machines. Today, this battery of machines is outproduced by one new 90-ton broaching machine, which operates at the rate of 137 pieces per hour.

METAL PLATING and solder adhere better to oxide-coated metals and glass by using evaporation techniques revealed by the Army Engineer Research and Development Laboratories. The vapors of two metals are deposited at the same time so as to eliminate oxidation. To coat titanium with copper, titanium is first evaporated on the oxide-coated titanium. At the first sign of titanium deposition, the evaporation of copper is begun. At the first copper deposit, the titanium source is turned off and the copper evaporation continued until no titanium shows through.

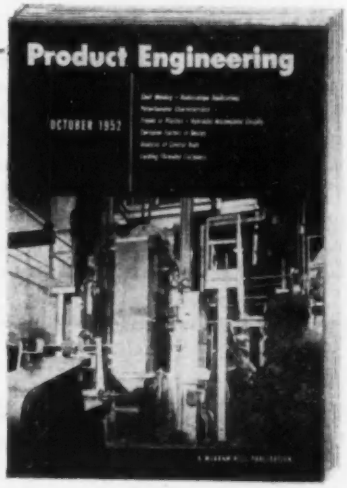
NO DEVELOPER is needed in the Perma-Stat process for reproducing half tones or line drawings on a non-porous surface. Developed by Trans Gel Prod. Inc., Queens Village, N.Y. and licensed to the Bettinger Corp. of Waltham, Mass., process consists of spreading a light-sensitive emulsion on a surface, placing negative of subject on the emulsion, exposing the latter to ultra-violet light, dipping in a dye and rinsing.

TESTING

RADIOACTIVE POLONIUM can now be purchased at Oak Ridge National Laboratory. This is the first reactor-produced radioisotope to be sold which emits alpha particles and neutrons. When bought for use as a neutron source, the polonium will be mixed with beryllium and enclosed in a small nickel cylinder. As an alpha source, the polonium will be plated on platinum. Procurement is by established procedures.

SYNCHRONIZED TRANSMITTERS and receivers are quickly checked with Type 226 Synchro Tester made by the Pennsylvania Testing Labs., Doylestown, Pa. Either 60 or 400 cps checks are obtained on every 10 deg of rotation to an accuracy of 10 sec by turning a selector switch that makes the required internal connections.

STEERING GEARS can now be tested with laboratory precision right on the production lines. Chrysler Corp. has a machine that determines the efficiency of each gear by operating it against a predetermined load. Previously, only a relatively small sampling of production parts and assemblies was checked in the laboratory.



THIS MONTH'S COVER

Pictured on this month's cover is one of the largest continuous annealers in the brass industry. It was recently placed in operation by Chase Brass & Copper Co. at their Metal Works Plant in Waterbury, Conn. Combining annealing and pickling treatments, this giant Drever machine makes possible substantial savings in time and reduces materials handling in the full-scale production of specialty sheet brass. In addition, the unit provides more exact control of heat treating and critical grain size than was formerly possible.

The annealer processes 140,000 lb of sheet per day. It stands 45 ft high and takes brass sheet up to 25 in. in width and as thick as .04 inch.

Another feature of the machine is that the material moves without interruption and at constant speed through the heat treating furnace and pickle tank. When the output is stopped to remove a full reel, idler rolls rise vertically to take up the slack. These rolls drop when reels of untreated material are being threaded into the machine. Thus, by varying the length of the material path through the machine, process speed is made independent of input and output speed.

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SPECIAL STAINLESS STEEL INNER WIRE BRAID IS SECURELY LOCKED TO INSIDE WALL OF TUBE. You get this added safety protection and assurance of longer hose life only with CONCORD #20 STEAM HOSE... another of BWH's significant developments in the field of mechanical rubber products!

Resists Tube Swelling

Withstands Tough Usage

Concord #20
STEAM HOSE

Here's the steam hose with built-in long life... in the form of a special stainless steel inner wire braid.

This inner lining is there to fight tube swelling under continuous high pressure... a condition that kills ordinary steam hose — and usually kills it *fast.*

Found only in CONCORD #20 STEAM HOSE, this protection helps assure retention of original inside hose diameter... acts against swelling and constriction of tube... promotes full flow of steam and easy recoupling in the field when necessary.

CONCORD #20 includes other construction features: two or three braids (depending on size) of alternate high tensile steel wire and rubber layers firmly bonded over outside of tube for maximum burst protection and safety; an asbestos braid for positive cover adhesion and cover insulation; a rugged, abrasion-resistant cover that withstands the toughest abuse.

Put CONCORD #20 to work for you now... get in touch with your nearby BWH distributor today.

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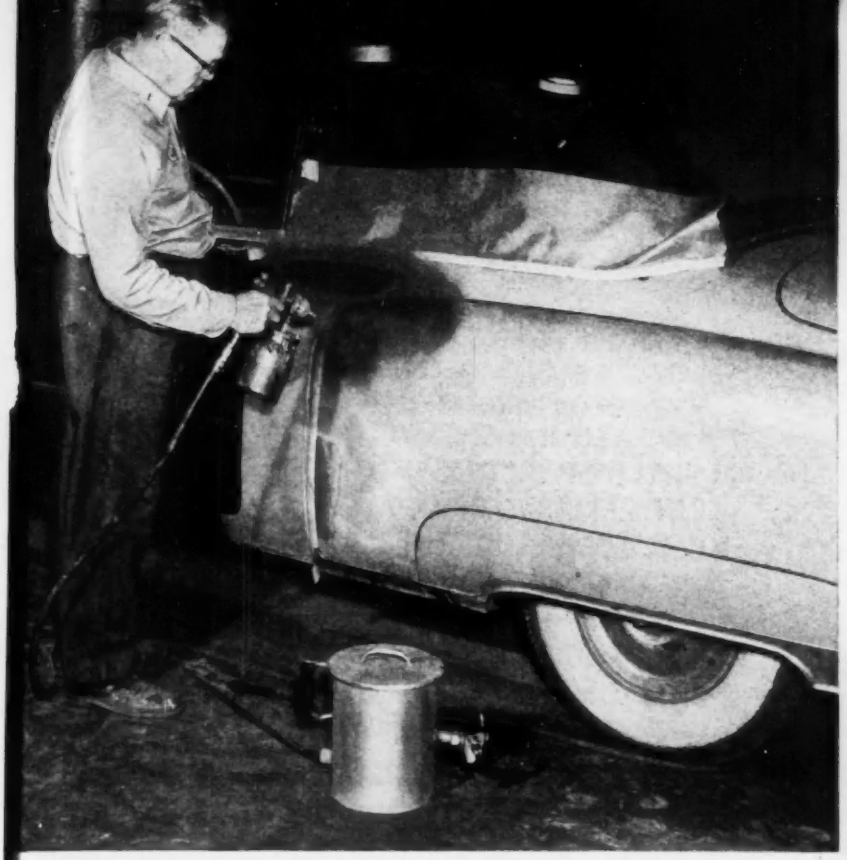

HOT SPRAYING APPLIES MORE SOLID PAINT QUICKER FOR A HIGHER QUALITY JOB.

DEPENDABLE CALROD* UNIT CHOSEN BY BEDE FOR NEW PAINT HEATER

Radical Savings in Time, Money, Materials Made Possible for Bede's Many Automotive Customers

Electric heat from Calrod heaters now reduces by 50 per cent the thinner used in automotive touch-up painting, according to Bede Products, Cleveland.

BEDE'S CUSTOMERS report savings such as: ". . . 25 to 40 per cent less material used, and up to 50 per cent less labor cost," experienced by a large Cleveland car dealer using hot spraying for retouch work.

The new model R automotive refinisher paint heater was developed by Mr. Bede after 18 years of experimentation and the manufacture of industrial heaters. The Model R uses a dependable long-life 650-watt Calrod tubular heater cast permanently into an aluminum plate to provide for an explosion-proof paint heater.

YOU, TOO, may have an idea for a new machine or equipment where heat is needed. Use high-quality Calrod heaters and take advantage of the years of experience G-E Heating Specialists have gained helping machinery and equipment builders install electric heat into their products for resale.

FOR MORE INFORMATION, call the nearby G-E Sales Office, or write to Section 720-84, *General Electric Company, Schenectady, N. Y.*

*Registered trademark

GENERAL ELECTRIC

DEPENDABLE HEAT from a Calrod heater makes possible this fast-moving, profitable item for Bede Products, Cleveland manufacturer of paint-heating equipment for the automotive industry.

A G-E HEATING SPECIALIST will help you design dependable, long-life Calrod heaters into your equipment or machinery for the big resale market. Get his services early in your planning!

EASILY FORMED Calrod heaters will give you clean, efficient, economical heat exactly where you want it, when you want it, and in the exact amount necessary for your every application.

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LINDE'S News of Metalworking

Sigma Welding...

A Process with Outstanding Promise

Recently, the country's biggest tank car manufacturer received the largest order for aluminum tank cars ever issued — ninety-eight tank cars on a single order. This order was obtained only because of the development of a fully automatic welding process . . . shielded inert gas metal arc welding — sigma welding.

This welding process has made double-vee butt welds at 5 in. per min. in 1-in. material. Structural welds have been made at 48 in. per min. in ¼ in. plate, and as high as 200 in. per min. on $\frac{1}{16}$ in. material.

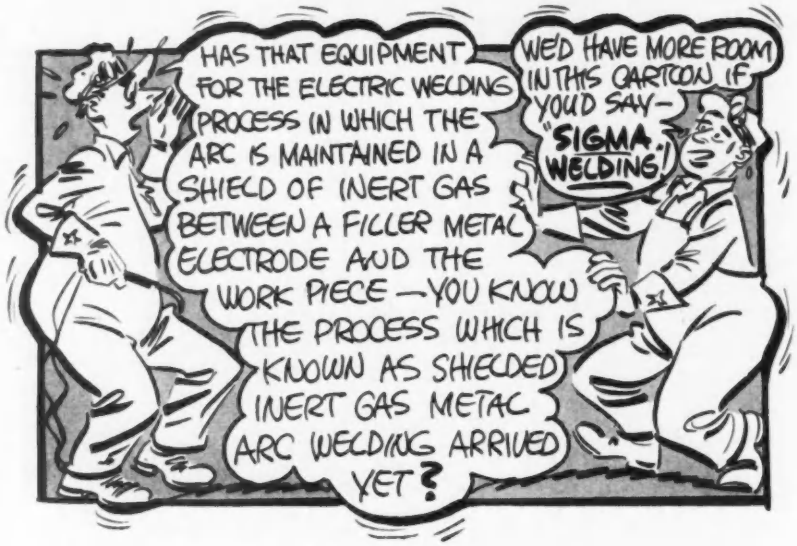
Prior to the development of sigma welding, fabricating aluminum tank cars was a slow hand process. In order to weld the heavy plates used in making the cars, as many as six passes were required.

With an automatic sigma welding setup, X-ray quality welds in the ½ to 1¾ in. thick aluminum plates are made at speeds of from 6 to 15 in. per minute. And only 2 passes, one inside and one outside, are required to get perfect penetration. High current densities used in sigma welding result in narrow welds with deep penetration.

Sigma welding is fast becoming an important fusion welding method. It has not only replaced many other welding methods, but has permitted fabrications hitherto impracticable for welding.

Just recently, a metalworker adopted this process for welding an aluminum-bronze valve seat to a mild steel tube . . . sigma welding proved to be the only practical method he could use for this work.

Another shop built their first *aluminum tank using sigma welding* . . . The large tank was finished so quickly — work progressed without stopping — that the shop will replace all other welding methods with sigma welding. Excellent welds *requiring little finishing* were obtained in the ½ in. aluminum plates.


HAS THAT EQUIPMENT FOR THE ELECTRIC WELDING PROCESS IN WHICH THE ARC IS MAINTAINED IN A SHIELD OF INERT GAS BETWEEN A FILLER METAL ELECTRODE AND THE WORK PIECE — YOU KNOW THE PROCESS WHICH IS KNOWN AS SHIELDED INERT GAS METAL ARC WELDING ARRIVED YET?
WE'D HAVE MORE ROOM IN THIS CARTOON IF YOU'D SAY — "SIGMA WELDING!"

New Processes Need New Names

The cartoon shows just about the way it started . . . Shielded inert gas metal arc welding was quite a mouthful to say when describing or referring to the process. It also required a lot of space in written material.

Then someone said sigma welding. It was easier to say.

Sigma is a good word, too. Each of the letters is an initial letter of the words: shielded, inert, gas, metal, and arc.

This easy-to-say word, sigma, is now used to describe the process. It is not a trade-marked word, and is used in the same sense as oxy-acetylene welding, gas cutting, or brown dog — just like any other descriptive adjective.

Metals Being Joined by Sigma Welding

Sigma welding can be used on practically all commercial metals. Railroad tank cars, chemical and food processing tanks, pressure vessels, and brewery equipment are only a few applications where the process is being used economically. Here's a quick look at some of the metals being joined by this process:

Aluminum . . . All weldable grades including 3-S, 50-S (150-S), 52-S, 61-S, and the commercially pure 2-S alloy are being welded with excellent results . . . These alloys are being machine welded in thicknesses ranging from 0.50 in. to 1.50 inch . . . Hand welds are made in material ¼ in. and thicker . . . Maximum thickness that can be welded is unlimited with multi-pass technique . . .

Stainless Steel . . . Sound X-ray quality butt welds have been obtained in thicknesses ranging from ¼ to ½ inch . . . Quite evident that heavier thicknesses can be welded . . . Results of tests show that welds possess good tensile strength, elongation, and impact resistance . . .

Copper . . . Sound butt, fillet, and corner welds have been made in ⅛ in. and ¼ in. deoxidized copper.

Everdur . . . Butt welds made in ⅛, ¼, and ½ in. thick materials are sound, smooth, and without cracks or undercutting. Tests showed that bend and tensile specimens have excellent properties.

Carbon Steel . . . Sound machine butt welds have been made in ⅛ in., ¼ in., and ½ in. thick killed and semi-killed carbon steels . . .

Aluminum Bronze rod has been deposited on mild steel with excellent results . . . Wear resistance greatly improved . . . Other surfacing and buildup operations very successful . . .

Perspectives ~ DESIGN AND DEVELOPMENT

WASHINGTON METALS OUTLOOK

This is how Washington views the metals outlook for 1953:

Steel supply and demand in general will be in balance in the first quarter of 1953. Inventory limitations will be boosted from 30 to 45 days. The strike's effect on steel supplies has turned out to be far less serious than anticipated. Virtually all steel deliveries to defense contractors will be caught up by the start of next year. The outlook is bolstered by forecasts of record-high steel production in the fourth quarter.

Product by product, these will be very tight until the second half of 1953: cold-drawn and hot-rolled carbon and alloy bars; plates; nickel-bearing stainless; carbon and alloy seamless tubing; and wide-flange structural shapes. Loosening up in the first quarter will be cold-rolled, galvanized, and hot-rolled sheet; cold-rolled and hot-rolled strip; and seamless pipe. Already in adequate supply are tin plate; hot-rolled rods; straight chrome stainless; tool steel; and welded tubing. The shortage in alloy steels is primarily a matter of long lead-times. Demand is dropping sharply.

Lifting of CMP, a strong possibility for the second quarter, would not boost steel demand substantially. In fact, there's belief that steel output may drop to 85 percent of capacity in the second quarter. There has been no mad rush to place orders since the strike settlement. The steel companies may have a big selling job on their hands.

COPPER IN BALANCE

Supply is now in balance with foreseeable demand and should remain that way through next year. Even if CMP is retained, consumers will be able to buy all the copper and copper-base alloys they want in 1953, and use the metal without restriction. Already brass and bronze are so plentiful that many mills and foundries are now crying for business.

The supply-demand balance could be upset next year, however, by large-scale government stockpile buying, increased military expansion, and a general revival of consumer hard-goods buying.

The balance in copper was achieved more quickly than mobilization planners thought possible. The reasons: the great increase in imports (fostered in part by the threat of a domestic strike), buying of consumer hard goods (which cut industrial demand).

BASIC METAL SHORTAGE

The problem in copper has been a shortage of the basic metal in contrast to steel and aluminum, where the problem stemmed from the need for new producing and fabricating capacity. In copper, there's absolutely no need for additional capacity. Since 1950 the only expansion has been to replace obsolescent equipment.

Total U. S. copper consumption is now 10 percent more than pre-Korea. The increase has been taken up by boosted imports of refined copper. Domestic demand for copper should grow about 45 percent over the next 25 years, the President's Materials Policy Commision recently reported. To meet the growing demand, the U. S. will have to double imports. There's little chance of a hike in domestic output. The trick here is simply to maintain current production rates as much as possible. Main deterrent is the sizeable disparity between the domestic ceiling price and the uncontrolled world price.

(Continued on page 117)

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FOR PRINTED OR
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now available!

metal-clad

INSUROK® T-725 and T-812

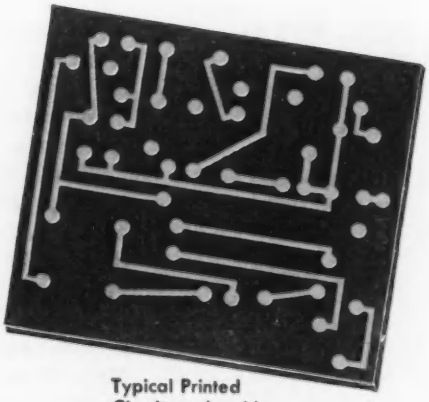
plastic laminates

Laminated INSUROK Grades T-725 and T-812 have made history ever since they were first introduced to the electronics industry. These laminates, possessing a unique combination of properties, have shown sensational performance in critical high-frequency applications.

Now these superior electrical laminates are available in *Metal-Clad* form (with copper or aluminum sheet bonded to one or both surfaces) for the production of "printed circuits."

Metal-Clad INSUROK exhibits outstanding electrical properties which remain remarkably stable under repeated temperature and humidity cycling. In addition, it possesses high physical strength and low cold flow, and punches readily into intricate shapes. The metal foil is bonded by a special process assuring consistently higher bond strengths than ever offered before.

Samples of Copper or Aluminum-Clad INSUROK are available for testing purposes. Send for complete information, today.



Typical Printed
Circuit made with
Metal-Clad INSUROK

The RICHARDSON COMPANY

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DEMAND PROBLEM

While there is little question of copper supplies next year, the big headache for producers may be one of immediate demand. Although copper industry spokesmen may talk down the danger of aluminum substitution for copper, this should be a big factor. Aluminum is cheaper than copper and has these qualities: it's a good electrical and heat conductor, is easily machined and worked, and is resistant to atmospheric corrosion. In addition, recent advances in aluminum welding technology promise to increase the use of aluminum still further in applications formerly reserved to copper and brass.

But the copper industry contents itself with a PMPC forecast than the demand for end-products using copper is likely to grow so much in the next 25 years that it will run ahead of supply. The industry also sees it this way: the more aluminum that's used, the more brass and copper, too. Copper industry spokesmen say aluminum will take the real big cut out of the market for steel and forest products, rather than out of the copper products market.

ALUMINUM STOCKPILING

Aluminum is now in approximate balance, while the degree of abundance in 1950 depends on stockpile plans. Currently there's relatively little stockpiling of aluminum ingot. DPA and the munitions board want to begin large-scale stockpiling in the first quarter. This would hold off abundant aluminum supplies for non-defense consumers until the second half of 1953. NPA'S aluminum division believes that stockpiling should wait until third quarter 1953, when there'll be enough aluminum from new capacity for all consumers.

In any case, we'll be out of the woods on aluminum next year. It's just a matter of what part of 1953. Aluminum expansion fell one-quarter behind schedule because of delayed plant construction resulting from the steel strike, power shortages, and inadequate scrap supplies.

To bolster the stockpile program, there'll be another expansion round of domestic ingot capacity -- with new producers. There has been controversy on whether we have enough facilities. The established producers and some NPA aluminum officials are inclined to worry about future demand for the new output. Everyone agrees however, that under full mobilization, there will be no lack of fabricating capacity.

Aluminum will be decontrolled by mid-1953. The feeling is that controls -- though not significant since most users can get the metal they now need -- is stifling new demand. Manufacturers are not going into aluminum whole hog it's said, for fear of inability to get the light metal. And until tremendous supplies are evident, aluminum demand won't go up substantially.

TIN, LEAD AND ZINC

Tin, lead and zinc will be in good supply. Tin controls will be dropped in the first quarter of 1953. The controls are now meaningless anyway. Tin allocations are big enough to meet all consumer needs, and liberal exceptions are being made to NPA'S inventory restrictions. Tin bought by RFC this year exceeds minimum national requirements by more than 20,000 tons. The surplus will go into the government's strategic stockpile. Private imports of tin, which have been recently resumed, will boosts supplies even more.

Lead and zinc, no longer under control, are plentiful. Consumption is below 1950 levels. Lead prices have dropped from 19 cents a lb. in February to 16; zinc from 19.5 cents to 14 cents -- and U. S. producers are cutting back production.

The problem according to the government, was to maintain domestic output. To prop up the markets, the government (1) set up a 30,000-ton "intermediate reserve" of lead, apart from the strategic stockpile, and (2) announced intentions to buy zinc after disclosures that the stockpile goal had been reached. Both moves pushed prices up 1/2 cent a pound.

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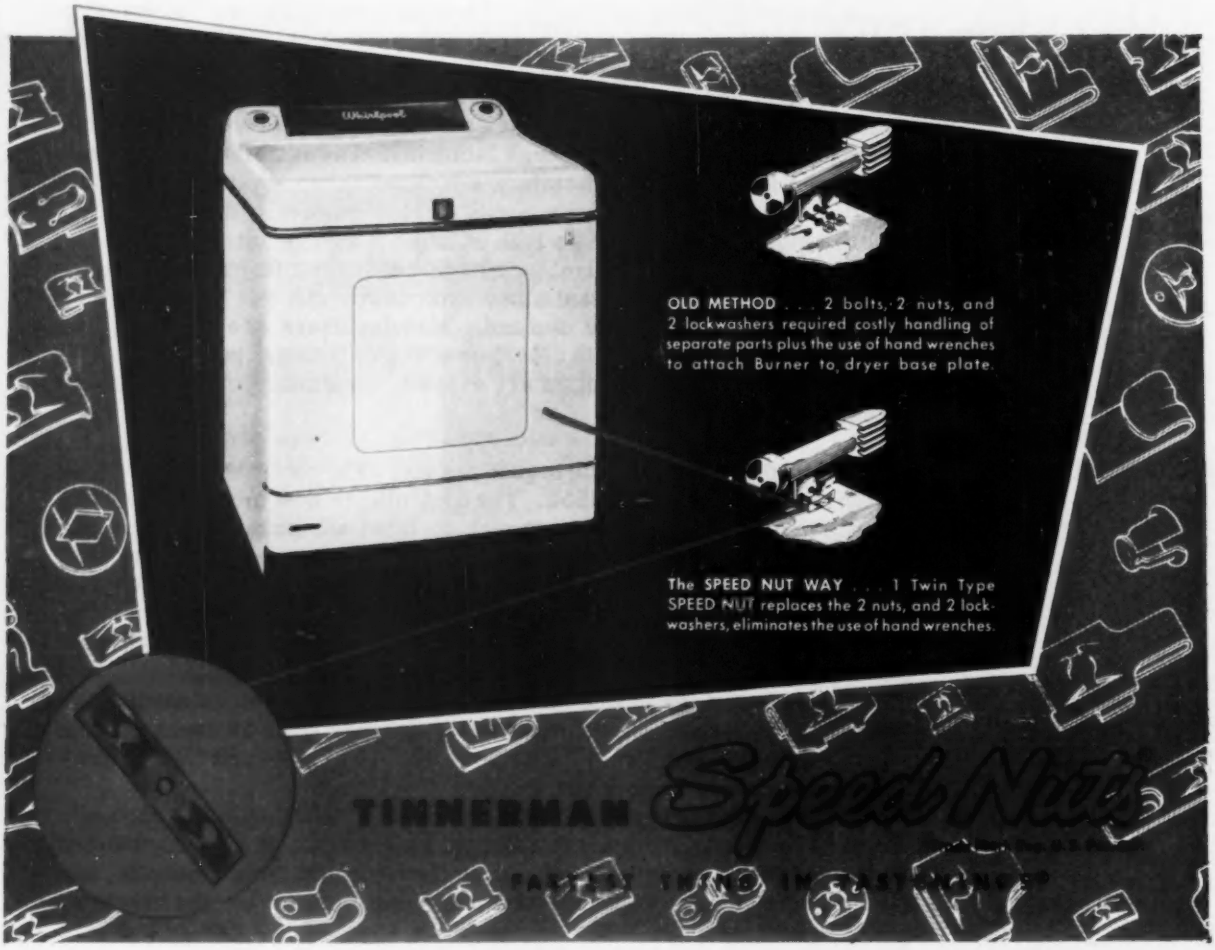
Whirlpool "TUMBLES" COST 37%

. . . on Clothes Dryer Burner Assembly!

How Whirlpool Corporation, St. Joseph, Mich., found Twin Type SPEED NUTS savings of 37%... reduced Materials Handling 75%

Whirlpool engineers have matched the smartly styled beauty of this automatic clothes dryer with smartly engineered, cost-saving fastening methods! In the complete dryer assembly, they have specified more than 40 SPEED NUTS of various types! Their latest find is a neat 37% production savings through the use of Twin Type SPEED NUTS in attaching the burner assembly to the base plate, eliminating two threaded nuts and two lockwashers for an amazing 75% cut in materials handling!

No matter what you build or assemble, whether you're in the design stages or in full production, there's a SPEED NUT way to solve your fastening problems! The TINNERMAN representative in your area will quickly supply detailed information on our FREE Fastening Analysis Service for your products. Call him soon! Meantime, write for your copy of "SPEED NUT Savings Stories", a booklet showing many typical TINNERMAN cost-saving solutions to a wide variety of fastening problems in industry. TINNERMAN PRODUCTS, INC., Dept. 12, Box 6688, Cleveland 1, Ohio. In Canada: Dominion Fasteners Ltd., Hamilton. In Great Britain: Simmonds Aerocessories, Ltd., Treforest, Wales. In France: Aerocessoires Simmonds, S. A.— 7 rue Henri Barbusse, Levallois (Seine) France.


Whirlpool
OLD METHOD . . . 2 bolts, 2 nuts, and 2 lockwashers required costly handling of separate parts plus the use of hand wrenches to attach Burner to dryer base plate.
The SPEED NUT WAY . . . 1 Twin Type SPEED NUT replaces the 2 nuts, and 2 lockwashers, eliminates the use of hand wrenches.
TINNERMAN Speed Nuts

Pouring molten stainless steel at 3100 F into unsupported shell molds. The good permeability of the mold walls is evident from the escaping burning gases.
Cooper Alloy Foundry

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Shell Molding

Saves Through Greater Mechanization and Less Machining

The shell molding process—the latest development in mechanized casting—offers greater latitude in the design of metal parts. It fills the gap between green sand casting and precision casting, offering advantages not found in either process.

THE TWO OUTSTANDING and reasonably substantiated advantages of the shell molding process are its adaptability to a high degree of mechanization and the obtainable savings in machining through closer tolerance casting.

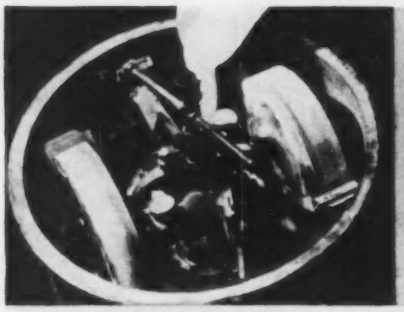
Each of these aspects of the process directly affects the design engineer. The equipment needed to mechanize the process differs considerably from standard foundry equipment. The design of new machinery will occupy a major position in the development and acceptance of shell molding. On the receiving end the product designer can take advantage of the close tolerances and machining savings offered by the process. In either case an understanding of the basic features of shell molding and its advantages and limitations is mandatory.

Mechanization

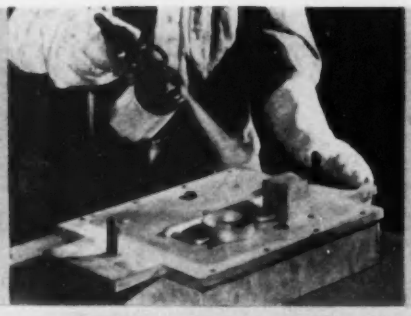
The field of machinery design for shell molding appears to be wide open. This no doubt stems from the fact that everyone connected with the process so far has been essentially a pioneer. Patent difficulties, real or imaginary, have prohibited exchange of detailed information. Everyone has to start from scratch with a knowledge of

Manual Shell Molding

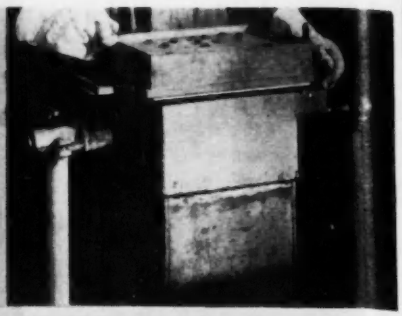
(Fig. 1)



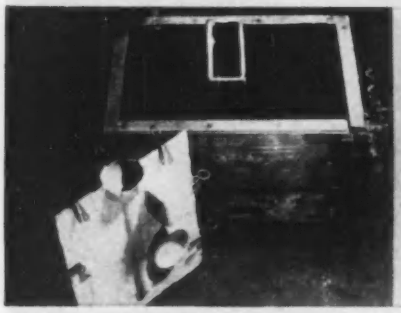
(a) Phenolic resin is mixed with 92 to 98 percent fine-grained sand.



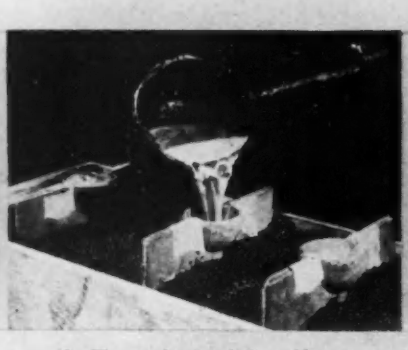
(b) Heated metal pattern is sprayed with a silicone lubricant.



(c) The hot pattern is fastened on the resin-sand filled dump box which is inverted to form a semi-cured mold.



(e) Two mold halves clamped together form the finished mold. In the rear is a conventional sand mold.

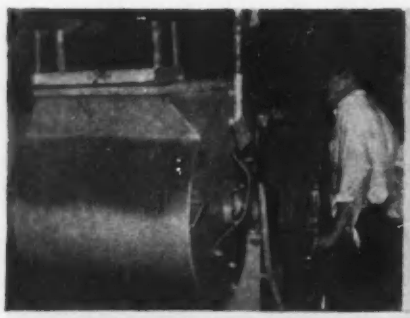


(f) The sand-resin shell molds are backed up by metal shot during pouring.

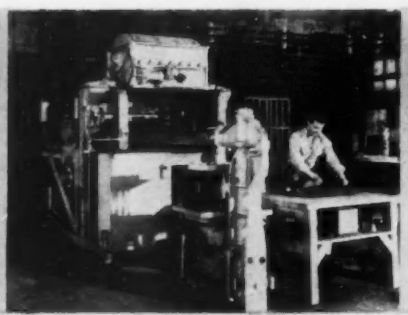
(g) The finished casting is readily knocked out of the brittle mold.

Automatic Shell Molding

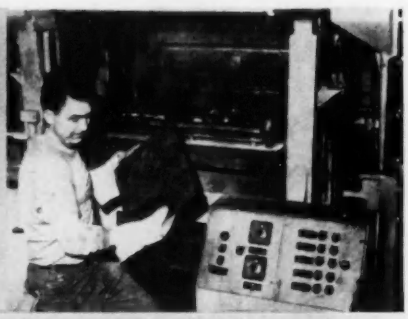
(Fig. 2)



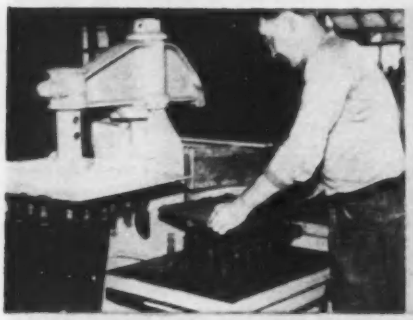
(a) The sand-resin mixture is automatically prior to filling the dump box on the shell mold machine.



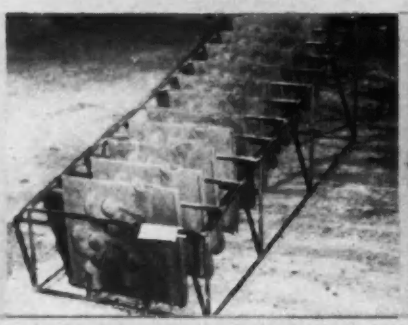
(b) The Shell Mold Machine Co. machine performs pattern heating, dumping and curing automatically.



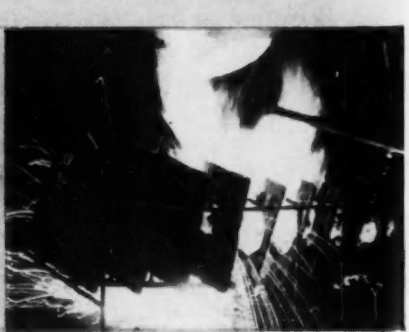
(c) After the automatic curing cycle the fully cured mold is removed.



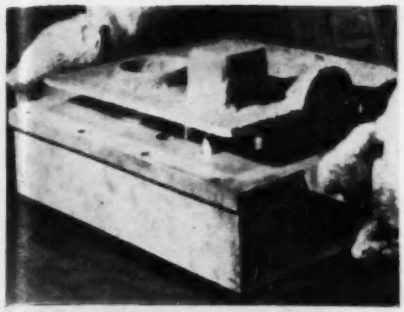
(e) A firm bond is produced by pressing the warm mold halves together.



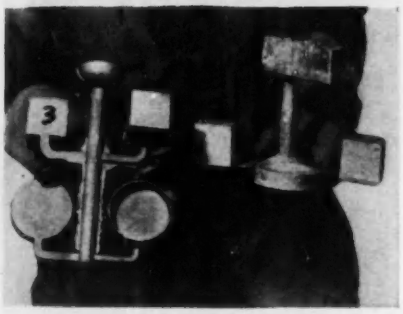
(f) Molds are set in racks. In this case no supporting material is used.



(g) A closeup of the pouring operation shows the gases escaping through the permeable mold walls.



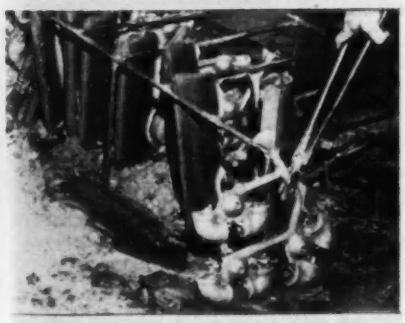
(d) After final cure in an oven the finished shell mold is separated from the pattern by stripper pins.



(h) The finished casting, left, compared to a green sand casting for surface smoothness.

Dow Chemical Co.

(d) Cores are inserted in the mold and the mold closed using bonding tape.



(h) After a few minutes the castings are knocked-out from the brittle molds.

Cooper Alloy Foundry Co.

only the fundamental principles of the process.

The basic concept of shell molding is the formation by heat of a thin walled, rigid, permeable mold from a mixture of fine grain sand and a thermosetting phenolic resin. This light mold replaces the bulky cope and drag sections of conventional sand molds.

The fundamental steps in the process Fig. 1 are: (1) Mixing of fine silica sand and powdered phenolic resin in a blender and transfer of the mixture to a dump box.

(2) Heating of a metal pattern for 15 to 20 seconds at 400 to 500 F and spraying it with silicone lubricant.

(3) Attaching the heated pattern plate to the dump box and transferring the resin-sand mixture to the pattern. The resin fuses to form a soft crust of resin and sand.

(4) Removing the pattern plate and adhering sand-resin crust from the dump box and transferring to an oven at 650 to 750 F. The curing cycle is usually about 2 to 3 min depending upon oven temperature.

(5) Removing the pattern from the oven and stripping of the cured shell mold.

(6) Clamping or adhering of the two mold halves together.

(7) In some cases backing up the shell mold with steel shot or sand.

(8) Pouring the molten metal into the mold.

(9) Knockout of finished castings.

The shell molding process lends itself readily to mechanization Fig. 2 because of its simplicity. Skill of the operator or foundryman, a major factor in green sand molding, is of minimum importance.

Molding machine manufacturers have presented various designs for automatic control of pattern heating, mold forming and curing and in some cases stripping and removal of the mold from the pattern. The operator is required only to start and stop the operation and to see that it is functioning properly.

Some of the companies presently engaged in automatic machine design and manufacture include Econocast, Inc., The Osborn Manufacturing Company, Shell Mold and Machine Company, Sutter Products and Winter Engineering Company.

The machines and their various parts must be designed to effectively carry out their functions in conformity with the theory of shell molding. This theory stipulates the following requirements for satisfactory results:

(a) Proper composition, purity and uniformity of the sand-resin mixture.

(b) Accurate control of temperature.

(c) Proper correlation of temperature and time to produce the correct thickness and cure of the mold.

The Winter Engineering Company, in designing one of their machines, Fig. 3, listed the following factors which they consider necessary for effective and efficient operation:

1. Automatic and accurately metered sand addition.
2. Removal of semi-cured or lumped mixture.
3. Automatic continuous heat control on the pattern and on the curing oven.
4. Elimination of pattern reheat operation.
5. Automatic pattern cleaning and coating.
6. Automatic finished mold removal to prevent excessive distortion and warping.
7. Maximum flexibility and adjustment of cycle and timing.
8. Ease of changeover for different jobs.
9. Unit, interchangeable construction for multiple head machines.

The first six points are in accordance with the theoretical principles of good shell molding practice whereas the remainder are concerned with effectiveness, flexibility and interchangeability of design. In Fig. 3 is presented the Winter Engineering Co.'s technique of putting these points into effect.

This machine does not permit a total mass of sand to strike the pattern at one time. The sand is allowed to fall through a height of 30 in. and the fall is broken to insure a gradual buildup along the sides of the pattern. This prevents arching and voids and uneven porosity that usually result with large volume dumping.

Heater plates on this machine are made adaptable to a varied arrangement of patterns. The assembly of the heater plate and pattern plate is made away from the machine so that temporary shut down during changeover is unnecessary.

Controlling Factors

Detailed data on the exact requirements for proper shell molds are not as yet available—at least for publication—and there is no doubt a lot of work to be done in this field. However, there are at least some obvious indications of the effects of various factors on the quality of the mold or the casting.

The presence of moisture contributes greatly to a reduction in the

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Whirlpool "TUMBLES" COST 37%

**How Whirlpool Corporation, St.
found Twin Type SPEED NUTS sav
reduced Materials Handling 75%**

Whirlpool engineers have match
styled beauty of this automatic
with smartly engineered, cost-sa
methods! In the complete dryer
have specified more than 40 SP
various types! Their latest find
production savings through th
Type SPEED NUTS in attachi
assembly to the base plate, eli
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Manual Shell Molding

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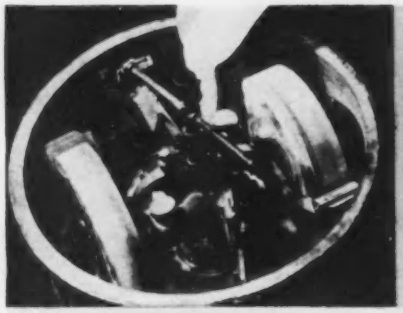
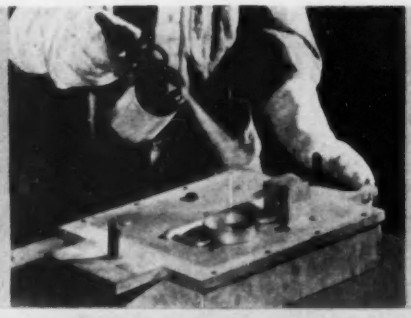
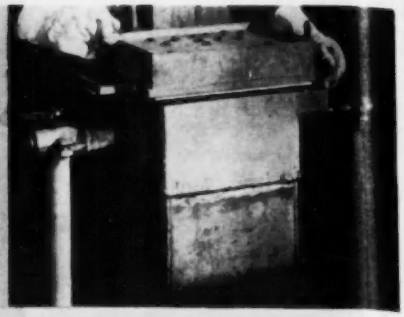


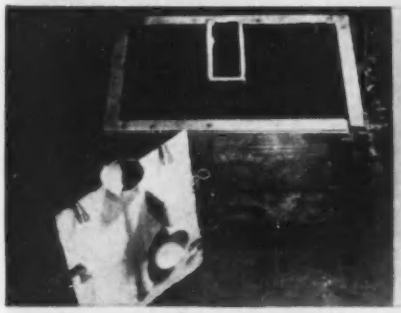
(a) Phenolic resin is mixed with 92 to 98 percent fine-grained sand.



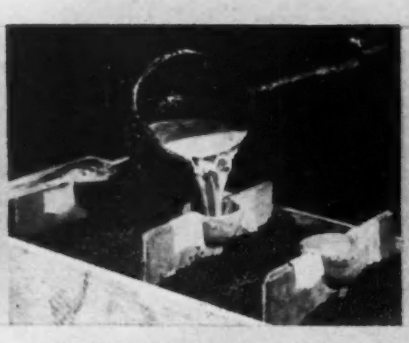
(b) Heated metal pattern is sprayed with a silicone lubricant.



(c) The hot pattern is fastened on the resin-sand filled dump box which is inverted to form a semi-cured mold.



(e) Two mold halves clamped together form the finished mold. In the rear is a conventional sand mold.



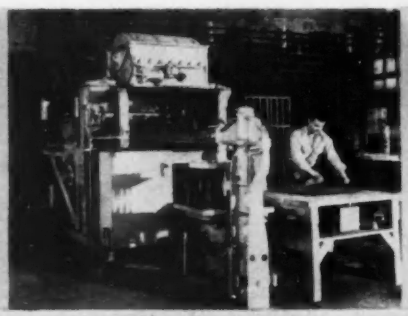
(f) The sand-resin shell molds are backed up by metal shot during pouring.

(g) The finished casting is readily knocked out of the brittle mold.

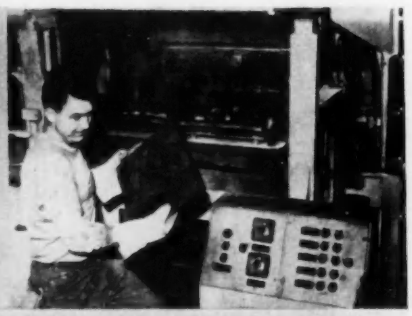
Automatic Shell Molding

(Fig. 2)

(a) The sand-resin mixture is automatically prior to filling the dump box on the shell mold machine.

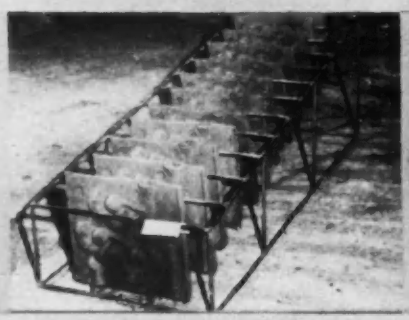


(b) The Shell Mold Machine Co. machine performs pattern heating, dumping and curing automatically.

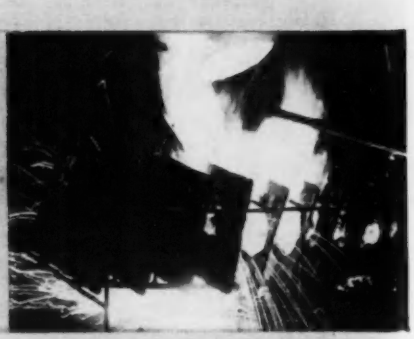


(c) After the automatic curing cycle the fully cured mold is removed.

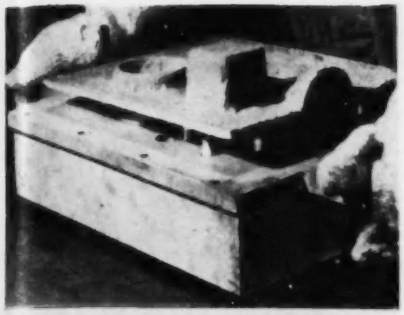
(e) A firm bond is produced by pressing the warm mold halves together.



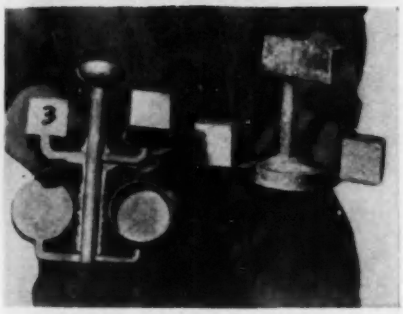
(f) Molds are set in racks. In this case no supporting material is used.



(g) A closeup of the pouring operation shows the gases escaping through the permeable mold walls.

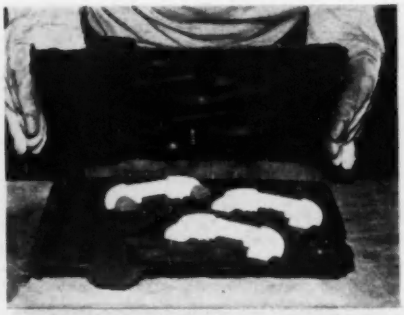


(d) After final cure in an oven the finished shell mold is separated from the pattern by stripper pins.

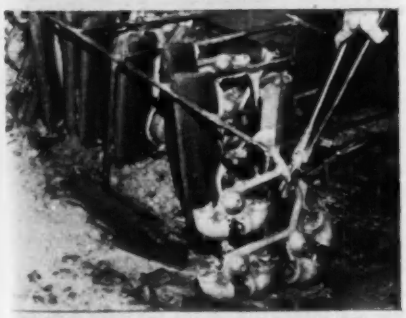


(h) The finished casting, left, compared to a green sand casting for surface smoothness.

Dow Chemical Co.



(d) Cores are inserted in the mold and the mold closed using bonding tape.



(h) After a few minutes the castings are knocked-out from the brittle molds.

Cooper Alloy Foundry Co.

only the fundamental principles of the process.

The basic concept of shell molding is the formation by heat of a thin walled, rigid, permeable mold from a mixture of fine grain sand and a thermosetting phenolic resin. This light mold replaces the bulky cope and drag sections of conventional sand molds.

The fundamental steps in the process Fig. 1 are: (1) Mixing of fine silica sand and powdered phenolic resin in a blender and transfer of the mixture to a dump box.

(2) Heating of a metal pattern for 15 to 20 seconds at 400 to 500 F and spraying it with silicone lubricant.

(3) Attaching the heated pattern plate to the dump box and transferring the resin-sand mixture to the pattern. The resin fuses to form a soft crust of resin and sand.

(4) Removing the pattern plate and adhering sand-resin crust from the dump box and transferring to an oven at 650 to 750 F. The curing cycle is usually about 2 to 3 min depending upon oven temperature.

(5) Removing the pattern from the oven and stripping of the cured shell mold.

(6) Clamping or adhering of the two mold halves together.

(7) In some cases backing up the shell mold with steel shot or sand.

(8) Pouring the molten metal into the mold.

(9) Knockout of finished castings.

The shell molding process lends itself readily to mechanization Fig. 2 because of its simplicity. Skill of the operator or foundryman, a major factor in green sand molding, is of minimum importance.

Molding machine manufacturers have presented various designs for automatic control of pattern heating, mold forming and curing and in some cases stripping and removal of the mold from the pattern. The operator is required only to start and stop the operation and to see that it is functioning properly.

Some of the companies presently engaged in automatic machine design and manufacture include Econocast, Inc., The Osborn Manufacturing Company, Shell Mold and Machine Company, Sutter Products and Winter Engineering Company.

The machines and their various parts must be designed to effectively carry out their functions in conformity with the theory of shell molding. This theory stipulates the following requirements for satisfactory results:

(a) Proper composition, purity and uniformity of the sand-resin mixture.

(b) Accurate control of temperature.

(c) Proper correlation of temperature and time to produce the correct thickness and cure of the mold.

The Winter Engineering Company, in designing one of their machines, Fig. 3, listed the following factors which they consider necessary for effective and efficient operation:

1. Automatic and accurately metered sand addition.
2. Removal of semi-cured or lumped mixture.
3. Automatic continuous heat control on the pattern and on the curing oven.
4. Elimination of pattern reheat operation.
5. Automatic pattern cleaning and coating.
6. Automatic finished mold removal to prevent excessive distortion and warping.
7. Maximum flexibility and adjustment of cycle and timing.
8. Ease of changeover for different jobs.
9. Unit, interchangeable construction for multiple head machines.

The first six points are in accordance with the theoretical principles of good shell molding practice whereas the remainder are concerned with effectiveness, flexibility and interchangeability of design. In Fig. 3 is presented the Winter Engineering Co.'s technique of putting these points into effect.

This machine does not permit a total mass of sand to strike the pattern at one time. The sand is allowed to fall through a height of 30 in. and the fall is broken to insure a gradual buildup along the sides of the pattern. This prevents arching and voids and uneven porosity that usually result with large volume dumping.

Heater plates on this machine are made adaptable to a varied arrangement of patterns. The assembly of the heater plate and pattern plate is made away from the machine so that temporary shut down during changeover is unnecessary.

Controlling Factors

Detailed data on the exact requirements for proper shell molds are not as yet available—at least for publication—and there is no doubt a lot of work to be done in this field. However, there are at least some obvious indications of the effects of various factors on the quality of the mold or the casting.

The presence of moisture contributes greatly to a reduction in the

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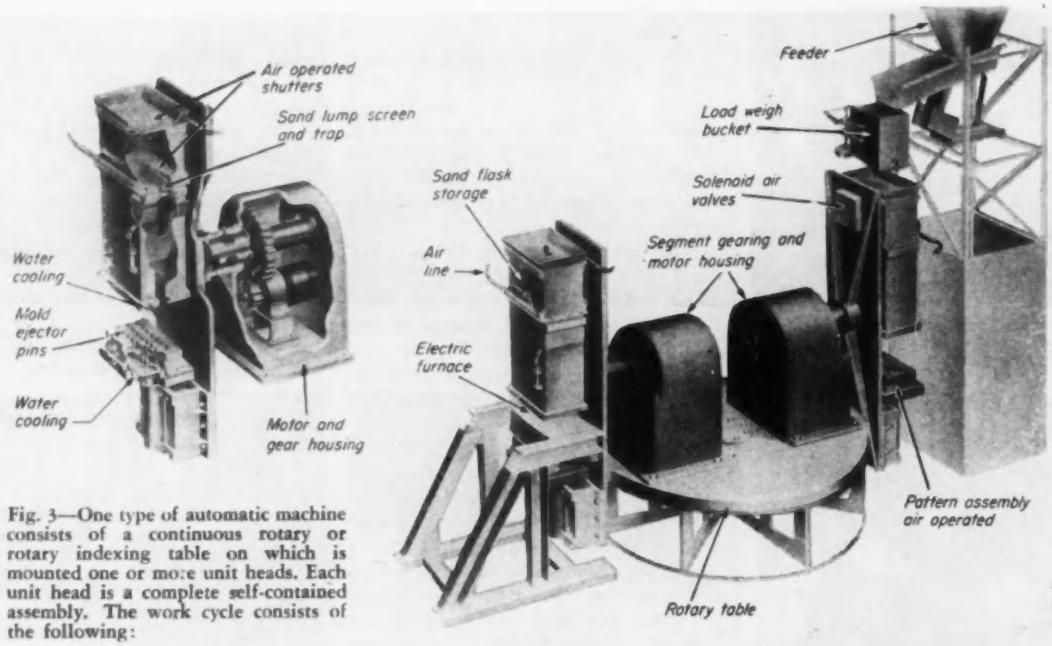


Fig. 3—One type of automatic machine consists of a continuous rotary or rotary indexing table on which is mounted one or more unit heads. Each unit head is a complete self-contained assembly. The work cycle consists of the following:

1. Pattern is moved up to sand flash by two air cylinders operated automatically by solenoid control valves.
2. Sand is dumped (left) by pneumatically opening the lower shutter in the sand flask. It falls onto the thermostatically controlled, electrically heated pattern for semi-curing.
3. After semi-curing the closed sand flask and pattern assembly are rotated 180 deg. to dump the excess sand-resin mix. This returning sand is screened through an electrically vibrated screen to prevent semi-cured lumps from entering the sand reservoir. The flask-pattern assembly continues to rotate to resume pattern face-up position. A side trap door and baffle panel swing and dump the semi-cured lumps.
4. Just before pattern face-up position is attained the pattern is withdrawn from the flask to allow clearance to permit the pattern and mold to enter the furnace (Station 2, right).
5. As the mold leaves the curing furnace, air cylinder operated ejector pins remove it from the pattern. Immediately upon stripping, the rods on the removing mechanism thread through the stripper pins and in rising pick up the mold whereupon the stripper pins are withdrawn. The mold then is rotated 180 degrees and dropped on either a rack or a take-away conveyor. During the 180 degree swing away from the machine provision is made for cooling by means of an air blast to the mold before it is touched by hand. The removal mechanism is provided with a flying head arrangement if automatic re-set takeoff is not required. An automatic takeoff however is provided to eliminate manual handling of the mold.
6. As soon as the mold is removed the pattern passes by a rotary brush, air nozzle and exhaust arrangement which cleans off adhering particles of sand. The pattern then passes under spray nozzles that deposit silicone lubricating solution on the pattern face. Generally continuous rotary machines with 6 heads or more are preferable for high speed production. For variety work and job lot runs a 2 head or 4 head rotary index machine gives better flexibility.

Winter Engineering Co.

strength of the mold shell. The phenolic resin used will absorb moisture and consequently precautions must be taken against leaving containers exposed.

Inadequate mixing, too fine sand, resin-sand separation and the presence of semi-cured or cured lumps will result in lack of uniformity of structure and will produce voids. Mold strength and permeability will be adversely affected and the finished casting will probably have rough spots on the surface. The design of equipment should insure thorough mixing, uniformity of composition and screening out of cured lumps.

Temperature Control—In automatic production of shell molds the governing factor is of course time, which is closely tied to temperature. A major part of the cycle time is consumed in forming and curing the mold. Both the thickness of the mold and the state of cure are functions of time and temperature at which the resin-sand mixtures will cure satisfactorily.

Closer control of mold wall thickness can be maintained by close control of the temperature of the pattern. Keeping the temperature constant by incorporating heating elements into the pattern plate contribute to uniformity of thickness.

The state of cure of the mold and consequently its strength are dependent to a great extent on good control of oven temperature.

Too low a curing temperature will not produce strong enough molds in a reasonable time. Too high a temperature can result in a friable surface and in excessive warpage. Generally mold cure times run from 15 to 45 seconds depending upon the mold thickness.

Each of the steps in the shell mold process must be thoroughly studied to better learn where savings in cycle time can be materialized.

Machining Savings

Savings in machining of shell molded parts over sand molded parts result from the following mechanical and metallurgical advantages:

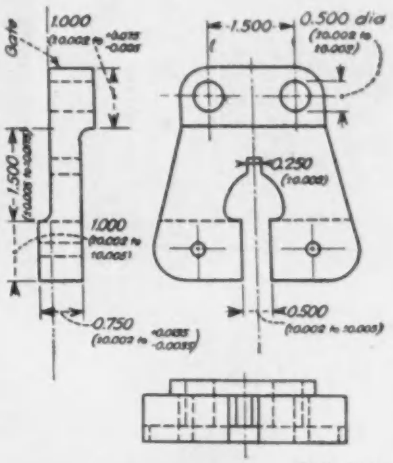
(1) Better dimensional accuracy.
(2) Less shifting of the mold halves.
(3) Better surface appearance.
(4) Excellent reproducability.
(5) Thinner sections can be cast.
(6) Less metallurgical defects such as blowholes, porosity, cold sheets and included sand and dirt.

The features of a shell mold that produce the above improvements over a sand mold in the finished casting are its greater permeability, high insulating properties, good strength and smoothness of surface.

The dimensions and surface condition of the shell mold reflect accurately those of the pattern plate. Tolerances

Fig. 6—The minuteness of detail that can be reproduced in a resin-sand mold is indicated by this artistic pattern. The mold material is strong enough to retain the fine edges and contours without crumbling.

American Brake Shoe Co.



Westinghouse

Fig. 5—Some practical dimensional tolerances that can be held on shell molded castings are indicated on the above drawing.

American Brake Shoe Co.

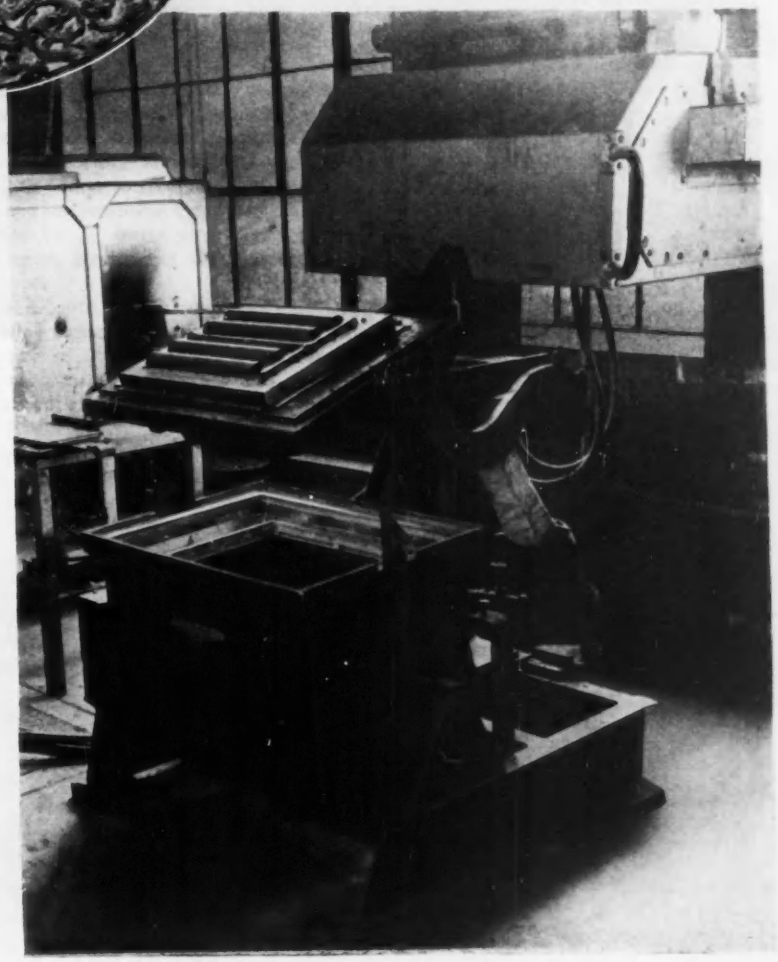


Fig. 4—The automatic shell mold machine manufactured by The Osborne Mfg. Co. has a tilting pattern plate and a swinging oven. The oven is shown in off position.

of between 0.002 and 0.005 inches can be achieved with well designed pattern equipment. A greater variation will occur across the parting plane. An additional 0.010 inch across the parting line would be reasonable. Fig. 5 shows practical tolerances for various typical dimensions.

The total variation in casting dimensions from the nominal will be the sum of three elements.

1. Variation from casting to casting —a normal distribution caused by uncontrollable variables.
2. Error in register and closure across parting line.
3. Shift from nominal caused by incorrect shrinkage estimates in design and manufacturing tolerances for the tooling itself.

The third element can be essentially eliminated where additional cost of correcting tooling can be justified. Wherever practical, drawing tolerances should allow for all elements

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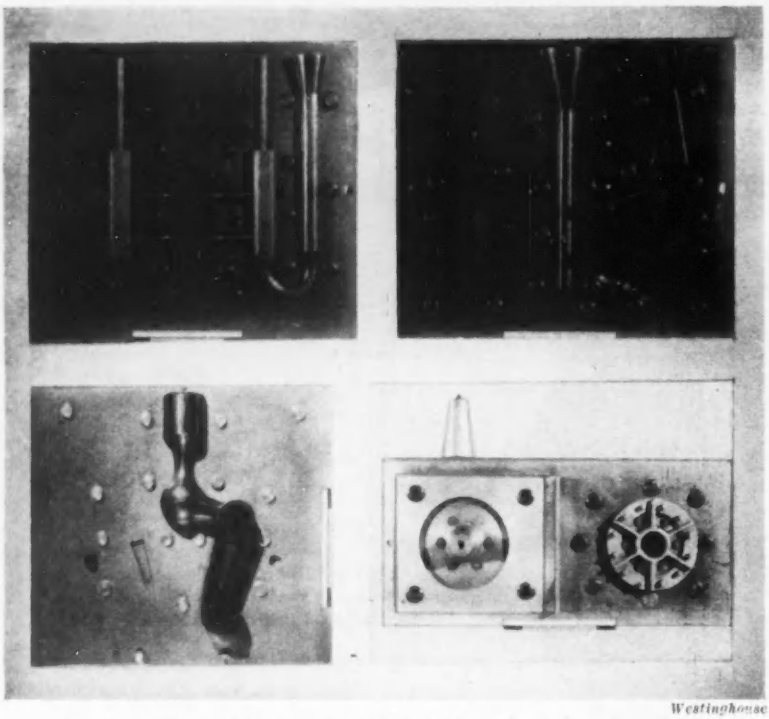


Westinghouse

Fig. 7—Above are shown some typical shell mold metal pattern plates.

and minimum tolerances should be specified only where essential.

Other Design Factors—The accurate and secure fit of shell mold halves prevents them from shifting while the metal is poured or while it is freezing. Consequently, in cases where holes are molded into a part, less drilling will be required to insure a clean hole.

The good mechanical strength of the shell mold allows some cores to be made integral with the mold. For example, a flange can be molded with accurately located and sized bolt holes without the use of inconvenient separate loose cores.

Metallurgical Advantages—Because of the high insulating quality of a shell mold, as well as its surface smoothness, better flow of the liquid metal is obtained. Casting of thinner sections is possible—down to about 0.010 inches. There is also less tendency for the formation of cold shuts. These are surface discontinuities produced when two streams of molten metal fail to unite because of premature freezing.

Greater reproducability of detail, Fig. 6, is also obtainable because of the improved fluidity. This is advantageous for incorporating printed information or company trade-marks on the metal surface.

Blowholes and porosity are reduced because of the permeability of the shell mold. In spite of the fact that the phenolic resin produces a gas when contacted by the molten metal, this gas and the dissolved gases liberated by the cooling metal are readily dispersed to the atmosphere through the permeable mold walls.

Dirt, sand and other foreign particles are prevented from entering the melt because of the inherent cleanliness of the shell mold and its tightly bonded sand-resin structure.

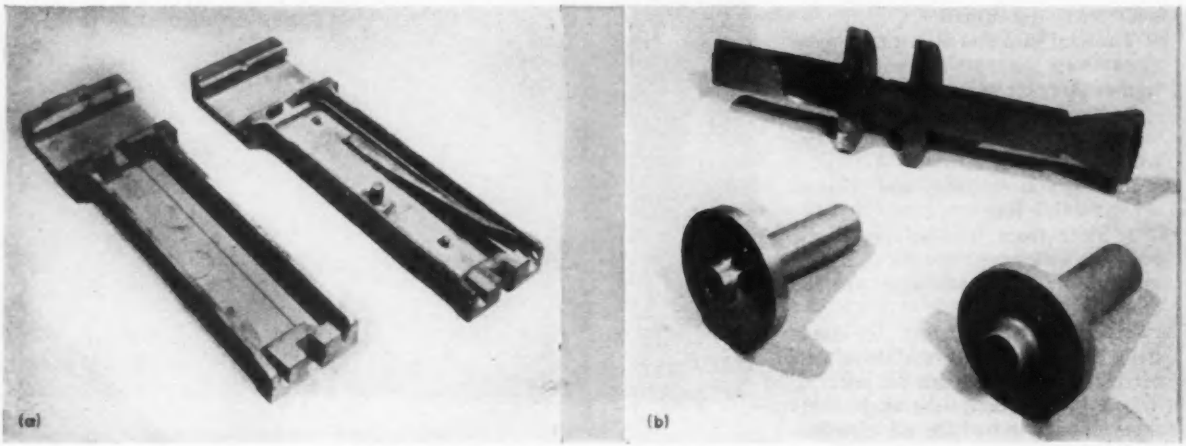
Castable Metals

Shell molding has been proved adaptable to aluminum, grey iron, nodular and malleable iron, low leaded tin bronzes, stainless steel and other highly alloyed steels. Some work, not entirely successful, has been done with magnesium.

The low carbon steels have so far remained a problem. The high melting point of these metals and the low viscosity of the melt have caused penetration of the metal into the mold surface with resultant roughness of the surface of the casting. This difficulty is also experienced with some stainless steels. The incorporation into the sand-resin mixture of various inhibitors has produced some improvement. Iron oxide powder is used in shell molds at Cooper Alloy Foundry Co. for stainless steel castings.

Gas turbine bucket blades have been successfully cast from high temperature alloys by shell molding. It is expected that this field will expand considerably. The cast material is claimed by some to have better high temperature properties than forgings.

Lead sweating of high tin bronzes still presents a problem in shell molding. The slow cooling of bronzes with a high tin content evidently produces greater segregation of the lead and allows more time for migration toward the surface.



Pattern Materials

The metals generally used for shell mold patterns include aluminum, grey iron and copper-base alloys. Because of the excellent reproducability of shell mold castings the surface of these patterns is required to be very smooth to gain this inherent advantage. Aluminum has the disadvantage of being easily nicked, it distorts at curving temperatures and it loses its surface smoothness under attack of the gases given off during curing. With the grey iron and copper alloys the major problem is oxidation and scaling which will interfere with heat transfer to the resin-sand mold.

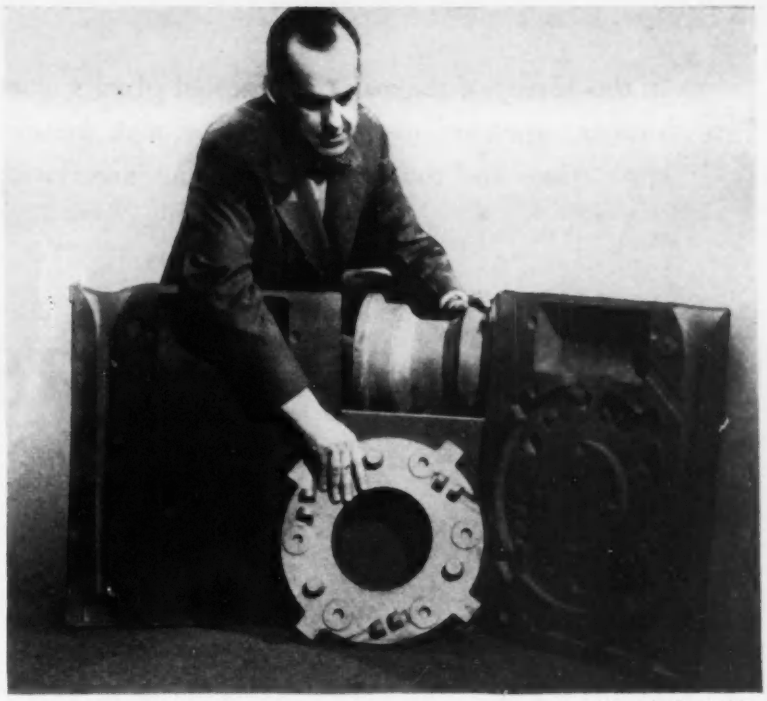
Limitations

Because of the limited strength of shell molds there are limitations on the size of parts that can be cast. Although castings approaching 200 lb have been successfully cast the best applications appear to be in parts weighing from 10 to 20 pounds—preferably in the 10 pound range.

If no extensive savings are possible in machining, the shell molding process will be economically feasible only for medium or high volume production items. It will therefore not be too suitable for jobbers or where only a few parts are required.

The high cost of patterns for shell molding still remains a deterrent to further growth of the process. These patterns must be made of a material that will withstand continuous or cyclic heating to high temperatures and must be machined to close tolerances and to a smooth finish to get full advantage of the potentials of the process.

As mentioned in the previous section, there are also limitations at present to the type of metal that can be cast satisfactorily.



Monsanto Chemical Co.

Fig. 8—Two large grey iron parts cast in shell molds at the Lynchburg Foundry

Outlook for Shell Molding

The shell molding process is claimed to be the greatest stimulus that has hit the foundry industry in many years. It fills the gap, with considerable overlap, between conventional sand molding and investment casting, giving the design engineer greater latitude.

There will probably develop through extensive research now underway a better understanding of the principles of metal solidification.

It is expected that further expansion of shell molding will result with the development of lower cost patterns, cheaper resin and smaller proportions of it and less costly and more flexible production equipment. In many cases the manufacturer will find it advisable to construct his own equipment from engineered units both from the standpoint of cost savings and adaptation to existing facilities.

The design engineer is caught in the middle. Many advantages are claimed for the process and for its product, yet the shroud of secrecy hinders dissemination and study of the facts behind these claims. When the industries doing shell molding get around to letting the design engineers in on it there will no doubt be stimulated activity in machine and product design, with subsequent improvements in the process and its products.

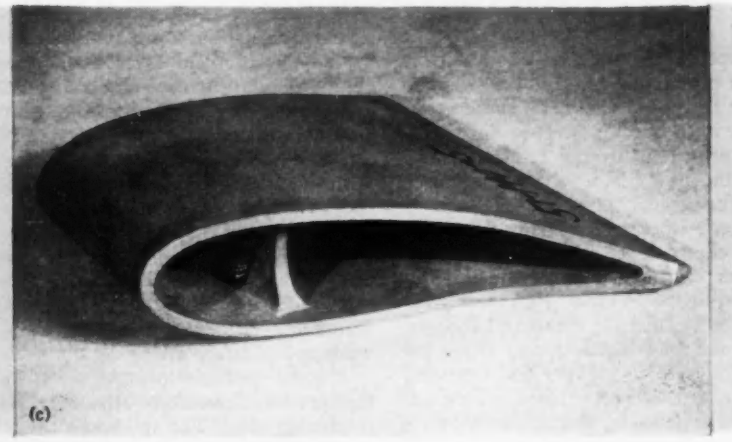


Fig. 9—Shell molded parts produced by the American Brake Shoe Co. include (a) Cover for machine gun, as cast, left and finished with inserts, right. Closer tolerance casting saved considerable machining; (b) Textile part which required close as-cast tolerances to allow chucking in automatic machines without changes in setting. The as-cast part is shown at bottom right; (c) Airfoil section requiring close control of section thickness.

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In this survey of the major commercial plastics, outstanding new uses of the various types are discussed together with the more important established applications and the properties of each material that suit it for these uses.

The Status of Plastics in

THE PAST TEN YEARS have seen a remarkable increase in the production and application of plastics. Improvements in formulations and in design have overcome many of the former limitations of these materials. In the last two years impetus has been added to the use of plastics by their relatively good supply compared to metals.

This survey of the major commercial plastics, their properties and recent applications will serve to indicate the general position and trend of plastics in today's industrial market.

Thermoplastics

There have been more new developments among the thermoplastics than among the thermosetting resins primarily because of their more diverse chemical structure with consequently more diverse properties. In addition to new materials, there has also been activity in developing new applications and improved formulations of established materials.

Nylon—The number of molded nylon parts has grown steadily as molders have come to understand the processing of the material and end-users have gained more experience with its products. The sharp melting point of nylon, in contrast to the indefinite melting point or long softening range of other plastics accounts for the processing difficulties experienced. These problems are now thoroughly understood and the designer can now find a competent molder for the material.

Nylon parts are used extensively in such fields as the automotive, business machines, textile machinery and builders' hardware because of their good abrasion resistance, low coefficient of friction, and the ability to dispense with lubricant under light load at high speeds or under moderate load at lower speeds. Also, they may cost about one-sixth as much as equivalent parts machined from brass or steel.

Other important properties of nylon include: Resistance to cold flow and deformation under load; service temperature of 400 F and more; good aging properties indoors; light weight and consequently low cost per unit; moldability in extremely thin sections and around delicate inserts, allowing flexibility of design not available to many other plastics. Thus, there are small nylon coil forms with flanges less than 0.01 in. thick. It's chemical resistance plays a roll in some uses, its low embrittlement temperature (lower than —70F) in others.

The automotive field is one in which many new applications have been proved out but not yet adopted because of uncertain production conditions. Firmly established, and in almost universal use, are nylon dome-light lenses (or diffusion covers), fuse holders, and striker blocks, which fit into a receptable in the door frame, acting as a positioning block to ease the bolt into the lock. The nylon speedometer gear introduced in the 1951 Ford saved 50 percent in overall production cost of the part besides giving improved performance. The Hudson uses a nylon washer on the floorboard to seal the clutch pedal arm and to bear the brunt of the friction as the pedal is depressed. In the Packard, nylon serves as a flexible thrust rod for raising and lowering the motor-driven antenna: both its rigidity and flexibility are called into play, for when the antenna is lowered, the rod coils into a trombone shape. A pair of molded-in nylon gears engage a steel worm gear to make the mechanism operate quietly. Both nylon parts have been subjected to 80,000 cycles without indicating excessive wear.

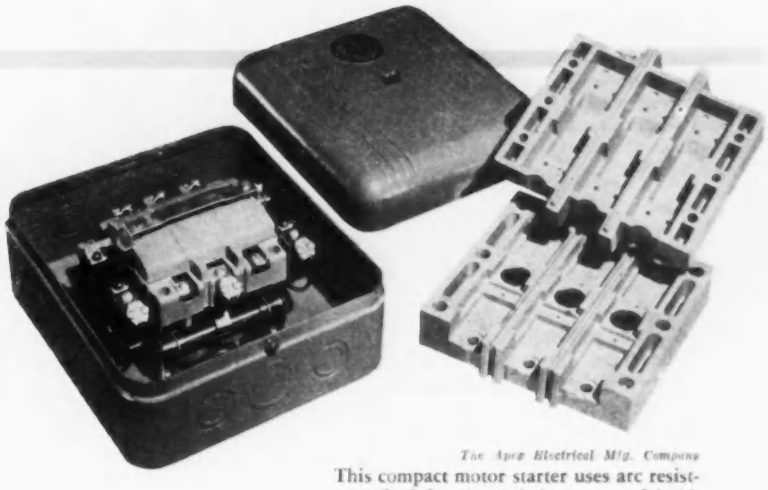
The textile field has devised more diverse applications than any other industry. Only specialists would be familiar with the exact uses of these parts, but merely to name them, with an indication of their function or merit, should be suggestive to the designer; roll-end bushings virtually eliminate wear and oiling; a parallel block requires no lubrication, absorbs shock; bolsters save power and reduce or eliminate lubrication; a nylon verge plate in a full-fashioned knitting machine costs less, requires less resurfacing; a nylon tension pulley is durable, flexible, and resumes its shape after distortion; low coefficient of friction commends nylon for a condenser which groups fibers and presents them to frontrolls.

Nylon's toughness comes into play in a whole series of fastening devices —conventional lock nut inserts, nuts with holes in them to receive nylon plugs to perform the same function, self-locking screws dispensing with nuts (as developed by the Nylock Corporation). A threaded die casting with the Nylok wedge is said to be in the headlights of all General Motors vehicles to hold the sealed beam headlights in proper adjustment. Nylok screws replacing 20 hold-down cap screws in an electrical control box eliminated the need for that many lock washers and safety wiring.

It is not possible to mold nylon to the precise dimensions attainable in machining steel. The minimum toler-

WILLIAM SCHACK

Industry Today



The Apex Electrical Mfg. Company

This compact motor starter uses arc resistant alkyd for the switch space and hold.

ance is ±0.002 inches on a 1 in. diameter; it is safer to count on a figure which all molders can achieve, which is ±0.005 inches.

The product engineer should also bear in mind that nylon moldings, like those of other plastic materials, are subject to residual stresses which will cause dimensional changes. To be on the safe side, he should specify relief of these stresses by heat-treating immediately after molding.

Vinyls—The next big development anticipated in the vinyl resins, is in unplasticized rigid polyvinyl chloride pipe. It has long been known that this type of vinyl is superior in several important properties to the elastomeric vinyl copolymers. It has a tensile strength of 7,000-9,000 psi compared to the latter's 1,400-3,000, and a water absorption of 0.07-0.08 percent as against 0.4-0.9 percent. It is also much more resistant to chemical attack; and many chemicals which might not affect the elastomeric compounds themselves attack their plasticizers. What has held back the earlier application of the unplasticized rigid vinyl material is its more difficult processability. It is now being processed in extruders of the screw type.

Because it is highly resistant to strong acids and alkalies, relatively non-toxic, and less than a fourth the weight of steel, rigid polyvinyl chloride pipe will serve for plumbing, irrigation and oil well lines, as well as in other underground installations and above ground applications where its corrosion resistance is desirable.

This material is also available in sheet stock for fabrication into small and large parts.

The processability of elastomeric vinyls is also being steadily improved. Constant study of the effects of lubricants and plasticizers have resulted in new formulations that speed up extrusion and molding, lowering the cost of the end product. Their beneficial properties are abrasive resistance, impact strength, weatherability, flexibility at low temperatures, light stability, oil resistance, and non-staining and non-migrating qualities.

The principal industrial use of Saran, the vinylidene chloride-vinyl chloride copolymer, remains chemical piping. Molded handles for a line of paint spray guns is another application of this material notable for its chemical resistance, low water absorption, dimensional stability and non-flammability.

Styrenes—Polystyrene has taken possession of the housewares field in such sensational fashion that its importance in other fields has been overlooked. Actually, the same percentage of the material was used in refrigerators until the shortage developed early last year—about 26 percent; another 20 percent was accounted for by radio, television and other electrical components, and packaging applications; and perhaps another 3 or 4 percent by fixtures. Within the past year further progress has been made in producing formulations of either straight polystyrene or copolymers with higher continuous service temperatures and higher impact strength. From the 0.25 to 0.40 ft. lb./in. notch on the Izod scale of standard polystyrene, the impact strength has been stepped up to as much as 5 ft lbs/in. notch, while the heat resistance of the newer formulations is close to 212 F as against 150-185 F for the standard grades. This material, with its excellent dielectric properties, low water absorption, high chemical resistivity and dimensional stability, has, in the improved formulations, also taken on the strength of the cellulosics, greatly increasing its all-around value. Hence the strong feeling in the plastics industry that the styrenes are due for such greater exploitation in industrial applications.

As the refrigerator market hardens again, it is expected to continue to increase its styrene components, in

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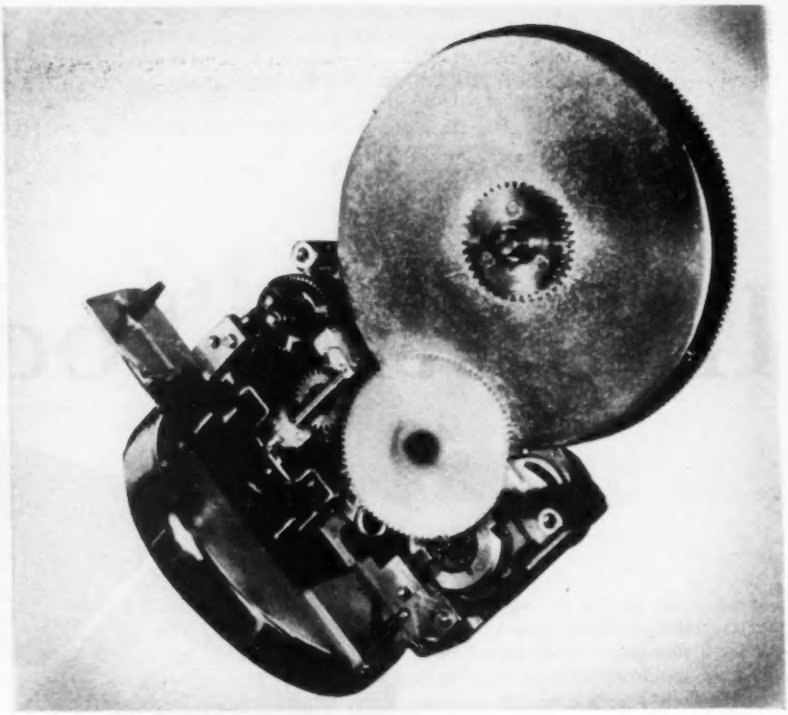
(Left) The gears of this home movie camera were machined from molded nylon blanks. The nylon gears run quietly without lubrication, absorbing the quick starts and stops of the camera.

Du Pont Company

(Right) (a) The two halves of this large reinforced plastic jet engine shipping container are very rugged and can be used in combat as water tanks or floats. (b) Glass reinforced plastic is used for a dish washing machine tub. This part measures 24x17⅞x17½ inches.

Bassons Industries Corp.



breaker strips, large panels, evaporator doors, baffle trays, inner doors, etc. Only recently the largest thermoplastic piece ever molded, an Admiral refrigerator door liner, was produced in Dow's styrene copolymer No. 475. Molded-in integrally with the body (which is 43 in. by 28 in. by approximately 6 in. deep) are supports for shelves, egg compartments and butter storage unit. This molding, weighing about 7.4 lbs, has set in motion thoughts for onepiece molding of such things as kitchen cabinets, washing machine tubs, lavatories and transparent aircraft enclosures.

In the electronic field, beyond radio and TV cabinets, the styrenes have had a variety of applications that promise to grow in both volume and number. With a loss factor of 25-70 $\times$ 10^5, over a wide frequency range, they have served in microwave relay systems. Machined pieces are used for printed circuits; molded ones for radiosonde parts. Polystyrene foil makes an excellent roll condenser.

As a storage battery case, polystyrene has the advantages of a specific gravity only slightly higher than that of water, a water absorption of 0.03 to 0.04 percent, resistance to battery acids, and dimensional stability under operating conditions. Greater use made of it in the remobilization program, in cases up to 5 lbs. may stimulate their use in industrial batteries and related applications.

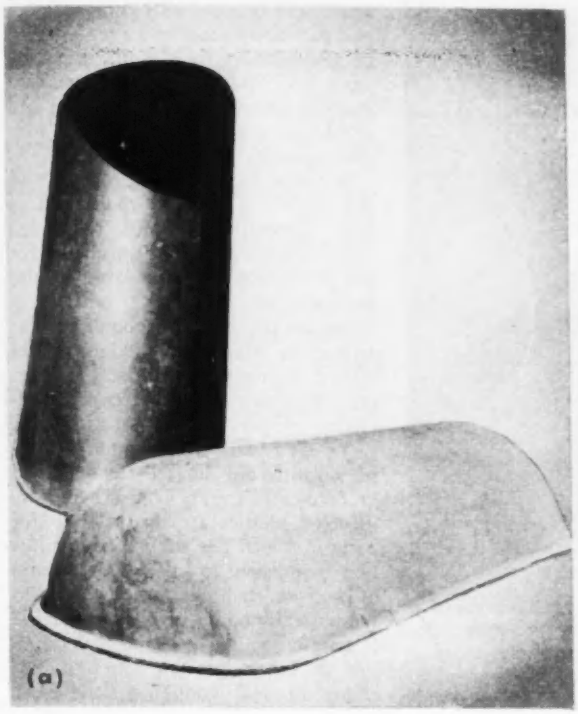
High-impact styrene is also being extruded for use as industrial and agricultural pipe; the most striking application has been in oil-well casing, not pipe-lines. While these uses cannot be said to have established themselves as yet, they bear watching.

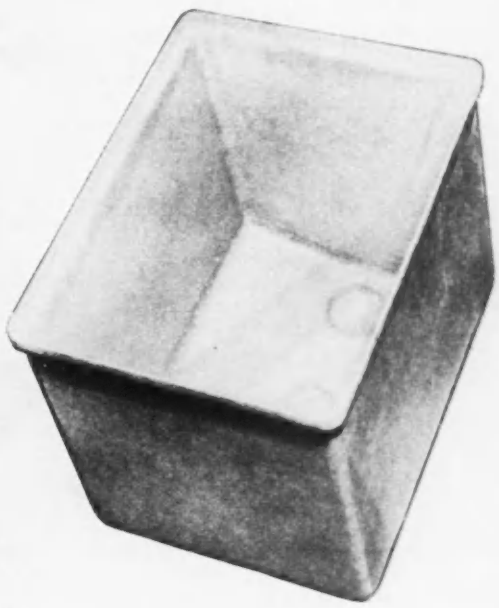
Cellulosics—In molded cellulosics there is the choice between cellulose acetate, cellulose acetate butyrate, and ethyl cellulose. There is an upward gradient in certain properties, as well as in price, in that order. Because of its toughness, low flammability and ease of molding and fabrication, acetate has been used for such purposes as radio and automobile knobs, business-machine keys, brush backs and the like. Its chief limitations are cold flow and susceptibility to dimensional change due to heat or water absorption, especially when it is used in combination with other materials. Generally speaking, those are the limitations of all cellulosics.

Butyrate may be called a median material between acetate and ethyl cellulose. Ranging in Izod impact strength from 0.7 to 5.4 ft lbs./in. notch (the latter for special formulations), butyrate is superior to acetate in this property at both the lower and upper limits (acetate's range is from 0.4 to 4.7), but inferior to ethyl cellulose, whose general purpose grades have a value of 2.0 to 7.0. In water absorption, butyrate's 1.4-2.1 percent also stands between acetate's 1.9-5.7 and ethyl's 0.8-1.8 percent. Where the optimum value for both of these properties is essential, as in certain vacuum cleaner parts, flashlight housings and refrigerator breaker strips (the material retaining its high impact strength at low temperatures), the use of ethyl cellulose is indicated. In some military applications also, ethyl's higher cost, about 10¢ more per lb than butyrate, is not a consideration. In turn, butyrate costs about 5¢ per lb more than acetate, and the designer must decide whether acetate's properties are adequate for his purpose or whether butyrate is necessary.

Automobile arm rests have in the last few years become a volume application of the material, approaching the poundage used in steering wheels. Its balanced properties have also commended it for use as the base of the telephone handset, and when color comes to the handset itself phenolic will be displaced by either acetate or butyrate. Butyrate's specific chemical resistivity to corrosion by salt water or earth soaked in crude oil or by electrolytic action has opened up to it an application that may exceed all others in volume—its use as pipe in oil fields in place of steel pipe, of which thousands of tons are corroded annually. The first butyrate pipe laid down over two years ago, a line to return salt water to the disposal well, was 800 ft long, 3 in. I.D., and with a 0.125 in. wall thickness.

Polyethylene—Another contender in the pipe field is polyethylene, which has been used in cold water systems, jet





pump installations, water drainage and exhaust systems for corrosive vapors. Its chemical inertness, physical toughness and light weight all have a bearing on these uses as they do on the material's application in enclosures and bottles, where its flexibility is also an important factor. If only for its higher cost, polyethylene is not apt to attain the volume of phenolics in caps and closures, but it should be remembered that its chemical resistance and impact strength, combined with its elastromeric properties, permit a flexibility of design not possible in other plastics suitable for the purpose. This is reflected in more varied decorative forms and in unique functional devices, such as spray orifices, self-hinged caps and retractable spouts.

Polyethylene-coated paper has become such an important packaging material that, with the important military needs still to be satisfied, the plastic is not freely available.

Fluorocarbons—Applications of the fluorinated hydrocarbons, Teflon and Kel-F continue to increase for components requiring the highest degree of chemical resistance combined with very high heat resistance. Teflon parts include bearings, impellers and packings in chemical pumps, gaskets for pipe flanges, pumps and reaction vessel closures, tape for motor insulation, and sheeting for roll type capacitors for high service temperatures (550 F and higher). Chemically, the material is unaffected by anything except molten alkali metals or fluorine above 300 F. Kel-F has also been used for gaskets and valve parts in chemical equipment, and its dielectric properties have made it useful in high frequency insulation, along with Teflon. As an example of the specialized function for which these materials can be called on, there is the graduated seal on an electrical junction box which is composed of a molded sheet of Teflon on one side and copper on the other. This dissipates any electrical charge on the outside, while the Teflon electrically insulates the inside.

Some companies now add a filler, such as glass, to the pure Teflon to increase its abrasion resistance for such uses as pipe flanges and small electrical coil forms. Here, wall sections as thin as 0.030 in. are possible.

Acrylic—No strikingly new applications have cropped up in this familiar plastic (Lucite, Plexiglas), but the old ones are worth recalling here for the properties which they depend on. High degree of transparency, dimensional stability and weathering resistance led to its use as aircraft canopies, outdoor signs and automobile trim. Add toughness, and you have the reason for acrylic machine guards and models for design and demonstration. Its transparency gives it the property of edge lighting, which is used not only for decorative purposes but also for inspection purposes in tools and medical instruments. Fixtures for display purposes, contact and other lenses, hearing-aid ear plugs are other diverse uses of acrylics.

Silicones—Not much has been heard of molded silicones, with their very high heat resistance (with glass fillers), high impact strength and fine weathering resistance. Aside from resins utilized as coatings, laminating and insulating varnishes, and lubricants, the most common form is silicone rubber. With their excellent resistance to heat aging, their flexibility at low temperatures (—76°F), and dielectric strength increasing with rising temperatures, the silicone rubbers are being used as gaskets and packing materials in contact with oils, hydraulic fluids and chemicals, and as insulation on motor leads and bushings in capacitors.

Thermosetting Resins

Reinforced plastics are the most promising of the thermosetting resins. An examination of some of the recent successful products indicates that a combination of simplicity of production and desirable properties led to the choice of reinforced plastics. Take, for example, the shipping container for jet engines which Bassons Industries Corporation is producing for the Wright Air Development Center. Cylindrical in form, 12 ft long by 5 ft. in diameter, the container is readily molded in two halves. With an O-gasket, these make an airtight fit when

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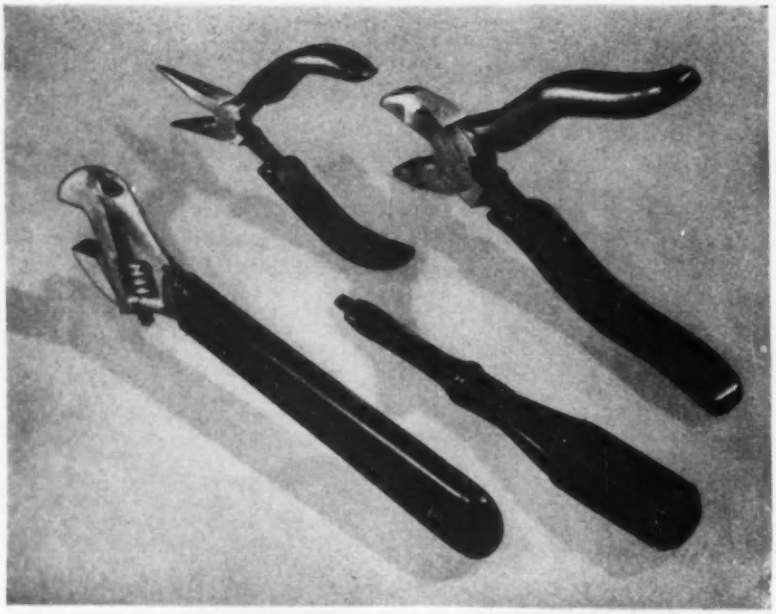
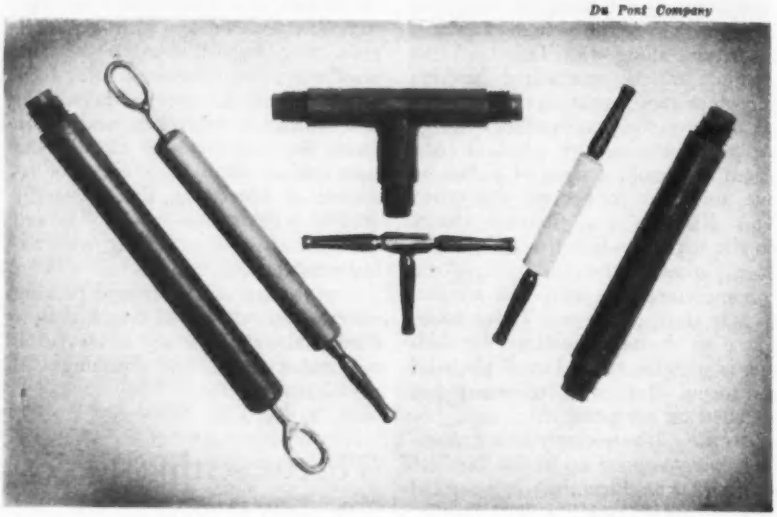


Connecticut Hard Rubber Company

(Above) Polyvinyl chloride-Hycar rubber blends are used as tool grips where oil ristance and good electrical insulation are required.

(Below) Tension units, tee splices and strain insulators of airplane antenna systems are insulated with polyethylene to reduce static interference, increase safety from static hazards and cut down maintenance.

Du Pont Company



they are bolted together after the engine is cradled. Mass production in matched molds, with ribs and other reinforcements molded in, makes possible a cost comparable with that of the former steel shipping containers, which weigh three and a half times as much and are correspondingly more difficult and expensive to handle.

At the same time the plastic container is moistureproof, fungus-resistant, electrically non-conductive and capable of withstanding heavy shock. Air Force service tests call for such rigorous procedures as edgewise and cornerwise drops, with the container fully loaded for shipment or with an equivalent dummy, allowed to fall freely successively from heights of 6 to 36 in. at 6-in. intervals.

The automobile body shown at this year's National Plastics exposition in Philadelphia is another important example of what is being done with reinforced plastics on a production basis. Towable target planes, soldiers' armor and helmets with visors, roofing and partition panels with a high degree of transparency, boat hulls, pipe for plant and underground use, washing machine liners, simulated shingles and tote-boxes are among the other new developments.

A prime factor in the economics of this plastic is that its mold cost is low. Generally speaking, reinforced plastics molding is to be considered for the production of fairly large articles in moderate quantities; articles of moderate size with compound curves; articles in which the strength-weight ratio is dominant (as in ducts and aircraft wing-tips); large parts where dielectric efficiency is important (as in radomes); parts which require a finish on only one surface (as a drawer or card-table top). Contrariwise, reinforced plastics are not suitable for parts in which the volume of production is sufficient to justify the expense of precision stamping dies, such as auto fenders and hoods, or where the article is simple enough in shape to lend itself to fabrication on standard machines, or small enough to lend itself to high-speed production by compressing molding. However, reinforced plastics can also make use of matched dies economically in many cases.

Alkyds—The polyester molding compounds introduced by Plaskon a few years ago, with mineral fillers, have advantages of high heat resistance (350-400 F), high electrical arc resistance (over 190 sec), and excellent dimensional stability, together with extremely fast molding cycles on inexpensive presses that make for low unit cost. Principal uses to date include television tuners and tube bases, capacitors, electrical connectors and switchgear parts. The chief drawback of the first formulations of the material was low impact strength, but new glass-filled formulations have overcome this limitation. These polyester resins can be molded easily around delicate inserts because of their plasticity and molded parts do not undergo aftershrinkage.

Phenolics—The old work-horse of the plastics industry shows no signs of flagging. Many new forms are available. Durez not long ago announced its electrically conductive phenolics—molding compounds that lend themselves to the simple production of chrome-plated parts. The molded plastic need only be roughened by sand—or vapor-blasted to be ready for electro-plating. Normally, on any type of plastic, a preliminary copper or silver film must be deposited on the roughened surface to receive the final desired coating. The

Durez materials are intended for products which can replace chrome-plate die-castings.

The rubber-phenolics blends, with their characteristic resilience making for high impact strength, introduced by General Electric's Chemical Dept. So far, most of their applications are said to have been for products which, for one reason or another, no grade of standard phenolic was quite right. Thus, a woodflour-filled rubber-phenolics composition took the place of a flock-filled straight phenolic in the terminal blocks of certain International Business Machines equipment, when cracks developed during assembly operations as metal contacts were press-fitted into the molded part and crimped into position. Worse cracking occurred when the tapered plugs on the connector wires were inserted into the contacts. With the blended plastic, there is also less cracking around large inserts when the molding cools.

A new Durez nubber-phenolic has a low modulus of elasticity so that products in thin sections can be molded around inserts. Impact strength is 50 percent higher than general purpose type. This material is not recommended for continuous service above 250 F.

Although these compounds will find more such replacement uses, there is also a growing trend to utilize them in parts especially designed to take advantage of their high shock resistance. In most of the applications where the blended plastic replaced the conventional phenolic, the old molds were used, and satisfactorily. But when a part is designed fresh, thinner wall sections and less reinforcement can be allowed for, reducing the cost.

Markets for this material are looked for in the textile equipment field. Another outlet is as a replacement for scarce metal parts. An application already in use is the silverware container in G-E's automatic dishwashing machine, in which the rubber-phenolic replaces brass screening. Another is the cylinder shield and handle of the portable tree saw manufactured by Precision Equipment Company, in which it replaces a cast magnesium alloy. A good opportunity is likewise seen for components in the automotive industry, in place of die castings. In the electrical industry the potentialities are indicated by an actual application to a bus bar insulation in which the ratio of copper to plastics is two to one. This points the way to the material's use in products where large inserts must be insulated and where sufficient heat is generated to crack a standard phenolic because of different coefficients of expansion. The rubber blend, because of its resiliency, can withstand such stresses.

Aside from the radically new phenolics, the standard grades are being improved, with faster cure, shorter molding cycles and longer flow characteristics (especially necessary for large parts), which make possible more economical use of compression and transfer presses. These formulations are for both old and new applications in housings, handles, bodies, closures and such electrical parts as switches, relays and special purpose wiring devices. In a recent model of a vacuum cleaner, the motor's carbon brush-holders were molded of phenolic around brass sleeves, demonstrating their resistance to the high heat generated when the cleaner was steadily used. Phenolics are also expected to make up a sizable number of the growing list of plastics components in electronic equipment (aside from the still valuable radio and television cabinet uses) where impact strength, thermal stability and low cost are required. The laminates, with their excellent punching properties, will play their part here, too.

Of almost revolutionary significance in the foundry field is the phenolic resin-sand shell molds which Monsanto and Bakelite are intensively developing. While this is a matter of processing, the product engineer should be aware of it as a source of better quality castings with lower finishing costs.

Much interest is being shown in a recently developed application because it is being sponsored directly by a materials manufacturer—cabinets developed by Bakelite from its own molds. Like sectional bookcases, these consist of top, base and variable number of drawers, all bound together by a steel thru-rod. All the parts are of sturdy construction, the drawers weighing 2½ pounds.

Melamine and Urea Resins—Although the applications of these two major amino plastics are likely to continue within the same well-defined areas in which they have figured for some years, the fact that the production of ureaformaldehyde was moderately increased last year and of melamine-formaldehyde substantially increased, without meeting the demand, is an indication of their growing usefulness. The greater share of melamine molding compounds goes into tableware with electrical applications holding the next important place. The mineral-filled grades, with their very high arc resistance, heat resistance and dielectric strength at both normal and elevated temperatures, have been extensively used in military aircraft ignition parts, and to some extent in civilian aircraft. Several hundred thousand pounds of plastics are said to be taken up each month for connector plugs in military electrical apparatus, made of melamines, as well as alkyds, polyesters and mica-filled phenolics. For commercial switch-gear equipment, woodflour-filled compounds are being used for watthour meter terminal blocks, automotive ignition components, television tube supports, connector plugs and insulation requiring high arc resistance.

It is often overlooked, however, that the melamines also have the highest resistance to arc tracking of any of the plastics, and that this property is in some applications of greater significance than arc resistance. The point is that, in the arc tracking tests, voltage is applied continually, while in the standard A.S.T.M. test, an intermittent voltage is applied, at least for the first three minutes. Therefore some materials which show up well under this test prove to be unsatisfactory in use when the potential is applied steadily. At the I.T.E. Circuit Breaker Co., Philadelphia, the arc tracking test employed is more nearly like the dielectric strength test, under constant potential, than the standard arc resistance test. The urea resins also have a high resistance to arc tracking, but they enjoy a rather restricted use in this field because they will not stand up under top temperatures in normal switchgear operation.

The principal use of the ureas is in adhesives for wood. As molding compounds, they have proved their value for closures, housings, wiring devices, stove and cabinet hardware and, to a lesser extent, radio cabinets. Normally, because of the material's excellent resistance to oils, greases and organic acids, its hard scratch-resistance surface, and richness of color and whites, it has played an important role in closures, though not nearly approximating the volume of the lower-cost phenolics. In the past year, ureas took the place of phenolics in this application when the latter was in short supply. Yet there is a strongly held view that they will not altogether yield their position to the returning phenolics. Because of reduced cost differential between phenolic and urea closures arising chiefly from more up-to-date cost accounting by closure molders, there is a distinct trend toward more urea closures with their color advantages. Even in such utilitarian applications as electrical plugs and switches fine urea whites are a significant factor for household purposes at least.

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More About Ceramic Coatings

Fig. 1

In November of last year, Product Engineering presented an article describing the ceramic coatings being used by the South Wind Division of Stewart-Warner Corp. for aircraft heat exchangers. Additional property information on those coatings plus data on newer types for high temperature alloys, ceramals, molybdenum, and resistance wire strain gages were obtained, much of it in an interview with William N. Harrison and Dwight G. Moore, who, at the National Bureau of Standards, developed many of the formulations now in production. Both NBS and proprietary coatings are discussed.

THE USE OF CERAMIC COATINGS to protect metals subjected to elevated temperatures and extremely corrosive operating conditions accomplishes one of two results: it prolongs the life of materials containing a large amount of strategic alloys, or it provides equivalent life for materials containing smaller amounts of alloys. Outstanding features of such coatings are (1) high resistance to chipping under repeated and severe thermal shock; (2) protection against oxidation in air and corrosive atmospheres at temperatures as high as 2,200 F; (3) freedom from the cracking and blistering produced in conventional porcelain under comparable operating conditions; and (4) a mat surface (when desired) that does not show highlights and therefore decreases visibility—important for military equipment.

Originally developed for collector rings and other components in aircraft exhaust systems, Fig. 1, ceramic coatings are being applied to muffles, dampers, and burners in industrial furnaces; heat baffles for enameling furnaces; heat exchangers; annealing boxes; muffles and exhaust pipes for trucks, automobiles, and tractors; and for other products operating under similar conditions.

General Characteristics

Ordinarily, metals exposed to elevated temperatures are protected by an oxide film that is impervious to the penetration of oxygen. Although thin, such films are self-healing and provide excellent protection below critical temperature limits provided that the part is used in an oxidizing atmosphere. If exposed to alternating oxidizing and reducing atmospheres or to certain corrosive atmospheres, such films lose their integrity and expose the base metal to deterioration, Fig. 2. It was to overcome these limitations and the limitations of existing finishes that ceramic coatings were developed.

One of the salient differences between ceramic coatings and conventional porcelain enamels is that the former have a much higher resistance to flow at elevated temperatures. They are also more refractory and maintain adherence over longer periods of operation and are designed to protect metals and alloys from atmospheric corrosion at or above red heat.

As a matter of fact, there is not much point in using ceramic coatings below red heat. Porcelain enamel usually will do the job equally as well

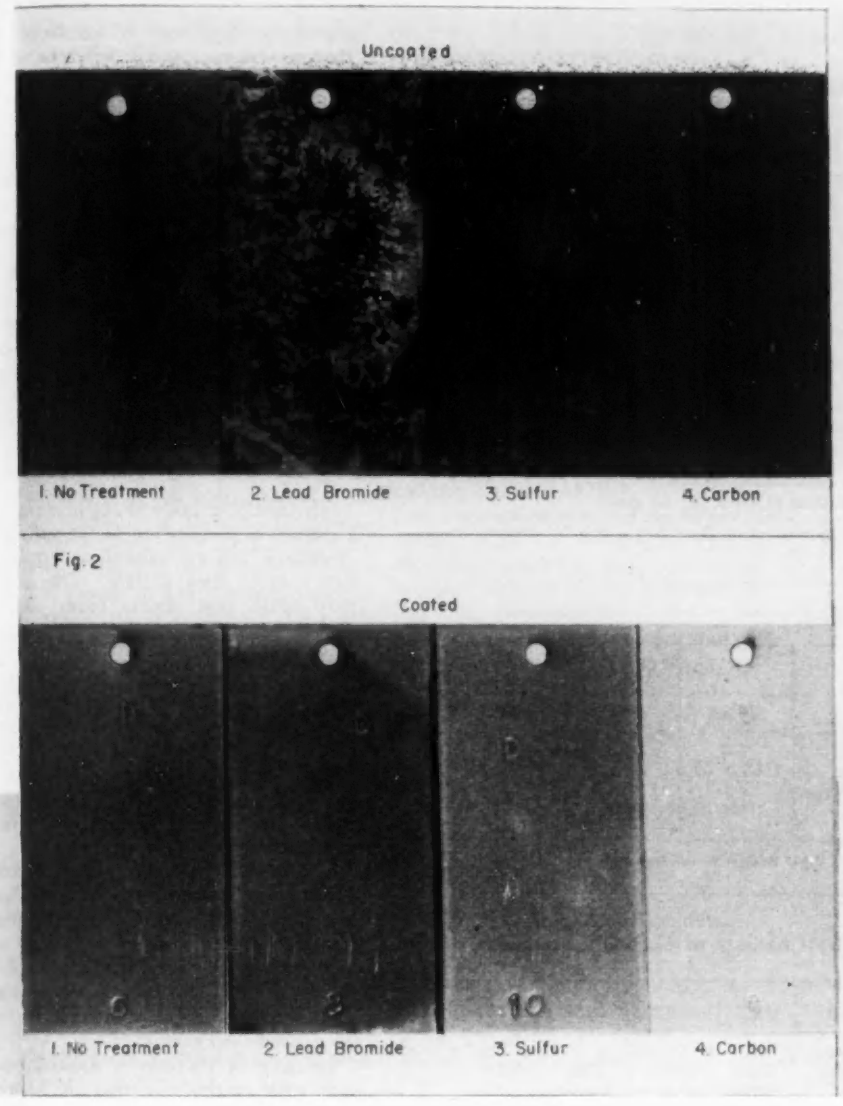

Fig. 1—These rolled spot-welded cylinders were alternately heated for 45 minutes at 1,800 to 1,900 F and air cooled for 15 min over a 16 hr. period. The part on the left is uncoated Type 321 stainless; the part at right is the same material coated. When subjected to a test of this sort, the protected Type 321 stainless remains unchanged after 200 hr exposure, while the unprotected type loses about 18 percent by weight.

Solar Aircraft Co.

Fig. 2—Corrosive gases are resisted by ceramic coatings. Lead bromide, sulfur, and carbon gases cause serious deterioration of uncoated Type 321 stainless (top). Coated stainless (bottom) is unaffected. Special coatings are also available when certain qualities are required that cannot be obtained in the base coat. Exceptional gall or abrasion resistance can be obtained for example, by applying a second coat over the base coat.

at lower temperatures. Thus ceramic coatings have maximum usefulness at temperatures from around 1,050 up to 2,000 or 2,200 F.

Actual Temperature Limits. Actual temperature limits depend not only on the composition of the coatings but also on the composition of the base metal. The base metal must operate below the temperature range at which creep or rupture might cause fracture. For example, the combination of NBS coating A-19 on low carbon steel would be limited to a maximum operating temperature of about 1,250 F for long time service at high stress.

Temperature limitations are strongly influenced by the stress conditions under which the alloy is being used. The stresses in the base of a turbine blade revolving at 12,000 or 15,000 rpm on a fairly large radius wheel, are extremely high, but in a piece of sheet metal that merely contains a parallel flow of gas the stress normally is low. Any statement that a specific coating or alloy is good up to a given temperature is obviously subject to qualification as to operating stress, type of atmosphere, and duration of service.

There seems to be considerable confusion throughout the industry whenever engineers start talking temperature. While the gas temperature within a given piece of equipment such as a jet engine might well be 3,000 F or higher, the temperature of a particular component, especially one only partially submerged in the gas stream, may be only 1,400 to 1,500 F, and under severe conditions probably would not exceed 2,200 to 2,300 F. In other words, a ceramic coated part might well withstand high gas temperatures because of the large flow of heat from the extremities to the cooler regions of the part.

Coverage. The porosity and coverage of a coating are extremely important, since its ability to prevent the atmosphere from reaching base metal is its prime function. Some porosity is desirable when a coating is applied to ordinary steel, since on being heated to approximately 1,100 F, the metal gives off a gas that must be liberated through the coating. While there probably is a minute amount of oxidization that does occur as a result of this porosity, the pores gradually fill up with oxide which itself has some porosity, and the amount of metal oxidization is limited and insignificant.

Resistance to Thermal Shock. Another property of coatings that is

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Table I—Composition and Application Data for Basic NBS Coatings

Composition

Ingredient	Parts by weight in —		
	A-19H (2)	A-417	A-520
Frit 11	100.0	——	——
Frit 331	——	70.0	90.0
Chromic oxide	——	30.0	——
Cupric oxide	——	——	10.0
Black cobalt oxide	1.0	——	——
Calcined alumina [1]	25.0	——	——
Enameling clay	10.0	5.0	6.0
Citric acid	.05	——	——
Sodium nitrite	——	——	.025
Water	50.0	48.0	45.0

1. Obtained from Aluminum Ore Co., East St. Louis, Ill., A-1 grade.
2. Differs from regular A-19 in that none of the softer frit (no. 1) is used. See Research Paper RP1773 of the Journ. of Research of the Nat'l Bur. of Stds. for composition of the regular A-19.

Application

Specifications	Coating		
	A-19H	A-417	A-520
Milling fineness [1]	1.0	0.4	0.3
Specific gravity of slip for dipping	1.60–1.62	1.78–1.82	1.85–1.90
Recommended fired thickness, mils	2–3	1.5–2.5	1.5–2.5
Firing temperature, F	1650	1850	1750

1. Grams on a No. 200 U. S. Standard Sieve using a 50-ml sample of slip.

Table II—Resistance of NBS Coatings to Carbon Penetration

Coating	Carburizing temperature (F)	AISI Type 304		AISI Type 321		AISI Type 347	
		Case depth (in.) (2)	Condition of coating (3)	Case depth (in.) (2)	Condition of coating (3)	Case depth (in.) (2)	Condition of coating (3)
None	1,350	0	——	0	——	0	——
A-19		0	C	0	C	0	C
A-417		0	I	0	I	0	I
A-520		0	M, S	0	M, S	0	M, S
None	1,500	0.020[4]	——	0.003	——	0.003	——
A-19		0	C	0	C	0	C
A-417		0.015	B, S	0	B, S	0.003[5]	B, S
A-520		0.015	M, W	0	M, S, W	0.001	M, W
None	1,650	0.030[4]	——	0.004	——	0.007	——
A-19		0	I	0	C	0	C
A-417		0	I	0	I	0	I
A-520		0.015	W	0.001	W	0	W

1. All specimens carburized for 4 hr at temperature.
2. Represents average depth to which alloy showed carbide precipitation at grain boundaries.
3. Letter symbols denote following coating conditions:
   - I coating intact; no major change in appearance
   - B coating blistered
   - M metallic copper at coating surface
   - C cracks in coating but not extending to alloy surface
   - S coating spalled but did not expose alloy surface
   - W wrinkled appearance of coating surface
4. Carbide precipitation occurred throughout structure of AISI Type 304 alloy at 1500 and 1,650 F but was more intense near surface. Because of gradual change in degree of precipitation inward from surface, case depth is rough approximation only.
5. Localized.

extremely important is resistance to thermal shock, especially when the part is heated or cooled rapidly. It is essential that the adherence be sufficiently strong to withstand the stress induced and still maintain its integrity. As a matter of fact, the principal reasons why the thickness of the coating is limited are that a thin film (1) has more resistance to thermal shock; (2) is less subject to spontaneous spalling; and (3) adds less to the weight of the part. And of course, if a thin coating is sufficiently impervious to keep the atmosphere from the alloy, there is really no reason to apply a heavy coat.

Methods of Application

The first step prior to application of a coating, is preparation of the surface. A ceramic coating cannot be applied to a smooth alloy surface. The ordinary finish that results from either cold or hot rolling is not conducive to maximum adherence.

Usually a sand-blasting or a pickling technique is specified to roughen up the surface. In some cases, it is even necessary to use both pickling and sand blasting—mainly because sand blasting is unsatisfactory for inaccessible areas. The pickling treatment is usually applied first.

The method that is commonly used to apply the coating is dipping. The coating material, which is made in the form of a water suspension or slip is adjusted for the right specific gravity and consistency, so that after being applied to the surface it will drain to the desired thickness.

Spraying of coatings is limited because most of the parts that are being coated today must be covered on the inside as well as the out—and it requires special spray equipment to reach the inside surfaces of many products. Also, dipping is a cheaper, more economical method of application.

After drying (Fig. 3) the coating is fired (Fig. 4) usually in air, at temperatures ranging from 1,600 to 1,900 F depending on its composition. For highly refractory coatings, a controlled atmosphere with a reduced oxygen content are necessary to obtain adequate adhesion on a mill steel base. Also, a complete absence of oxygen is necessary when firing a coating on molybdenum; in this case, either a hydrogen, argon, or helium atmosphere is used.

General rules reported by the South Wind Division of Stewart-Warner Corporation for coating ceramic materials on metals indicate that careful process control is essential. For example, pigmented lubricants cannot be

applied to the metal during pressing and forming operations (before coating) because no method of cleaning will remove the pigment completely, and burnoff heat will melt the pigment into the metal surface. This interferes with adhesion.

Spectrographic analysis of scale removed from heat-treated parts almost always shows traces of boron and sulfur, which would cause rapid scaling of the metal at firing temperatures. Thus, the coating could not be fired with acceptable results if any scale were present on the parent-metal. An electric furnace, with inert-atmosphere equipment available for optional use, is desirable both for heat-treating the metal after forming, and for firing the ceramic after it has been applied.

Ceramics can be applied over welds, but the welding flux should not contain fluorides, for the coating will not adhere readily to fluoride-treated metal.

Washing or degreasing metal parts before coating is not necessary if preliminary stress-relieving and sandblasting have been used to remove foreign matter from the surfaces. Part handling after sandblasting should be mechanical, because even a fingerprint will leave enough oil on the work surface to prevent coat adhesion.

There are five steps in applying a ceramic coating. Stresses are relieved in a continuous conveyor furnace. Low-alloy and cold-rolled steel are held at 1,200 F for around 2 min. High-temperature alloys are held at 1,500 to 1,800 F for 5 min. This burns off grease and dirt, and oxidizes the surfaces.

Next, a course sand is blasted onto the parts. Metal shot or grit are not applicable because they may contaminate the parts. Cold-rolled parts may be acid-pickled instead. Either process cleans and roughens the surface which improves holding qualities.

The coating is applied by dipping or spraying, depending on the character of the metal surfaces. Sometimes special fixtures are necessary to insure full coverage at the exact thickness required.

The fourth step is drying the slip in heated air, then wiping off any surfaces or edges that are to be left uncoated or are later to be machined or welded.

The last operation described by Stewart-Warner is firing in an electrical box furnace. Firing temperatures have been established for the different coating materials. Length of time in the furnace, after firing temperature is attained, depends on the thickness of the coat, configuration of the parts, and size of the load. For a load of 150 lb, total furnace time might run as high as 30 min.

If the coating is not adequate, some coatings can be patched and refired. If no repairs can be made, stripping is done by immersing the part in hydrocloric acid for six to eight hrs, then sandblasting. The part is heated to about 1,500 F to stop acid action, and is sandblasted again.

National Bureau of Standards Coatings

Several types of coatings have been developed, some by government laboratories and others in the research divisions of industrial concerns. The first laboratory to announce the development of special high temperature coatings for aircraft components was the National Bureau of Standards (June 1943). Since 1945, the work that is reported here on these coatings has been sponsored by the National Advisory Committee for Aeronautics.

Three of the NBS compositions currently are being used on a production basis: A-19, A-417, and A-418. Another, L6AC, has been used in this country and abroad to fasten strain gages to parts at elevated temperatures. Molybdenum coatings also are in limited use, as are coatings for ceramals or ceramets.

1. Coating A-19 was developed by NBS specifically for application on low carbon steels, and since then has been extended in use to austenitic stainless steels, Inconel, and Multimet N-155. As indicated in Table I, it usually is applied as a single coat finish thicknesses ranging from 2 to 3 mils; experience has shown that application in as heavy a coating as the conventional ground coat enamels causes spontaneous chipping. Although A-19 has a higher coefficient of thermal expansion than some porcelain enamels—$10x2x10^{-6}$ in. per in. per deg C—it may nevertheless be under greater stress after being fired and cooled to room temperature because of its higher melting temperature.

The firing temperature of this coating is 1,600 F. It cannot be subjected to high velocity gas impingement at substantially higher temperatures for prolonged periods of time without deterioration. At lower temperatures,

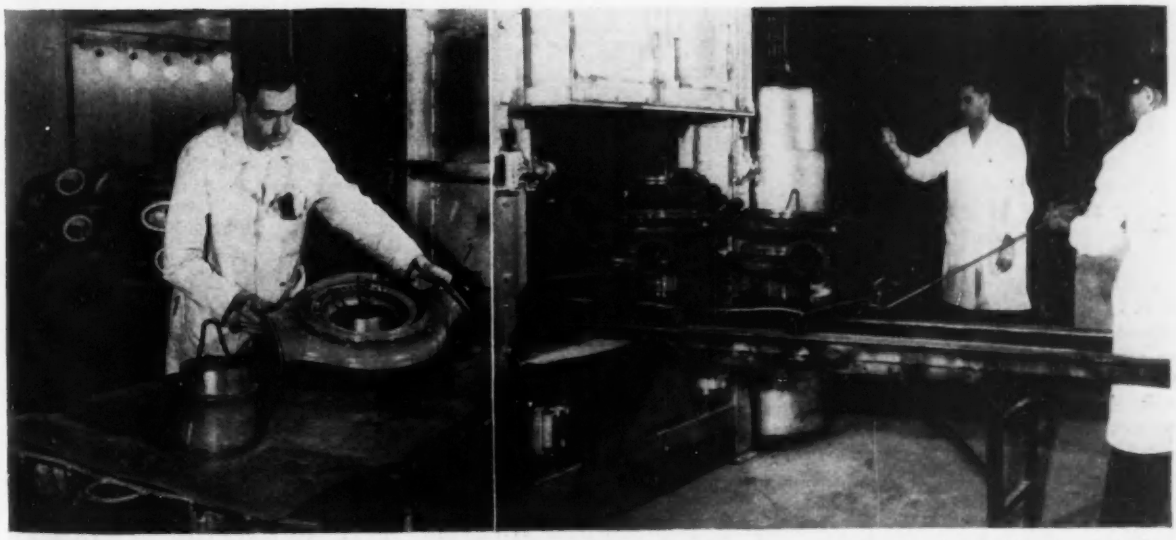

Fig. 3—(Left) Coated parts are dried in infra-red ovens after being covered with a ceramic coating. Careful handling is required at this point since ceramic coatings have no strength until fired at high temperature. Fig. 4—(Right) Turbosupercharger nozzle boxes coated with a high temperature ceramic being removed from furnace after firing. *Boldro Aircraft Co.*

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Table III—Batch Compositions for NBS Chromium-Frit-Type Base Coats

Coating	Composition					
	Chromium powder[1]	Frit 331[2]	Clay[3]	Water	$NaNO_2$[4]	Cellosolve
M-37	100	—	5	50	0.04	—
M-38	90	10	5	52.5	0.04	—
M-39	80	20	5	52.5	0.04	—
M-40	70	30	5	52.5	0.04	—
M-41[5]	100	—	—	—	—	35

1. Electrolytic grade, minus 200 mesh powder.
2. See Table II for composition of frit 331.
3. Florida kaolin.
4. Added to give suitable consistency to slip.
5. Mixed in beaker using manual stirring.

Table IV—Flame Resistance of NBS Chromium-Frit-Type Coatings

Coating[1]	Chromium in Base Coat, (percent by weight)	Specimens Tested	No. of specimens failed after 1-hr heating[2]	
			At 2,600 F	At 2,800 F
M-41	100	4	2	2
M-37	95	4	0	4
M-38	86	4	0	4
M-39	76	4	0	4
M-40	67	4	0	4
M-41-13	100	4	0	2
M-37-13	95	4	0	1
M-38-13	86	4	1	2
M-39-13	76	4	0	4
M-40-13	67	4	0	4

1. Number 13 following coating identification indicates that seal coat M-13 was applied over the chromium-frit-type base coat. Base coats were fired at 2,600 F in dry hydrogen using a molybdenum susceptor while seal coats were fired under same conditions except at 2,400 F.

2 Visible oxidation of molybdenum at any point on specimen was considered coating failure. Each specimen was tested first at 2600 F and if no failure occurred in 1-hr test period, specimen was retested at 2800 F. If failure occurred at 2600 F, no test was made at 2,800 F.

life depends upon thickness, composition of the base metal, nature of the corrosive gases present, and the shape of the part.

Although the softening temperature of A-19 is approximately 1,100 F as measured by an interferometer, it remains sufficiently hard so that objects placed in close proximity will not stick to it. However, it tends to flow off surfaces exposed to high velocity, and high temperature (1,700 F or above) gases. It must be applied to a completed product after forming and fabrication.

2. NBS coatings A-417 and A-418 are used exclusively on high temperature alloys such as Inconel, Multimet N-155, AISI Types 347 and 371 stainless steel, Haynes-Stellite alloys such as HS21 and others.

As with A-19, these coatings consist of a glass frit and a refractory admixture—in this case chromic oxide. One of the primary reasons for using chromic oxide is, of course, its good refractory properties. It is stable, does not readily change its valence value, and when applied to high chromium-containing alloys, helps to form a layer on the metal that is impervious to the penetration of oxygen. Most coatings in production today either have aluminum oxide or chromium oxide admixtures, and sometimes both.

The essential difference between A-417 and A-418 is that the latter does not contain beryllium oxide, and therefore eliminates the danger of toxicity. Although coating A-417 contains 2½ percent of beryllium oxide in the glassy phase, and something under 2 percent in the coating as a whole, it has been used in production for two years or more with no deleterious effect. There would be little reason to expect toxicity, but there are regulations, laws, and psychological objections against using any beryllium oxide whatsoever. It was largely to satisfy these objections that A-417 coating was modified.

Both of these coatings can be operated at temperatures 200 to 300 F higher than firing temperature. They are somewhat more difficult to apply than A-19, but are less brittle. (see PRODUCT ENGINEERING, Nov., 1951). Resistance to carbon penetration is indicated in Table II.

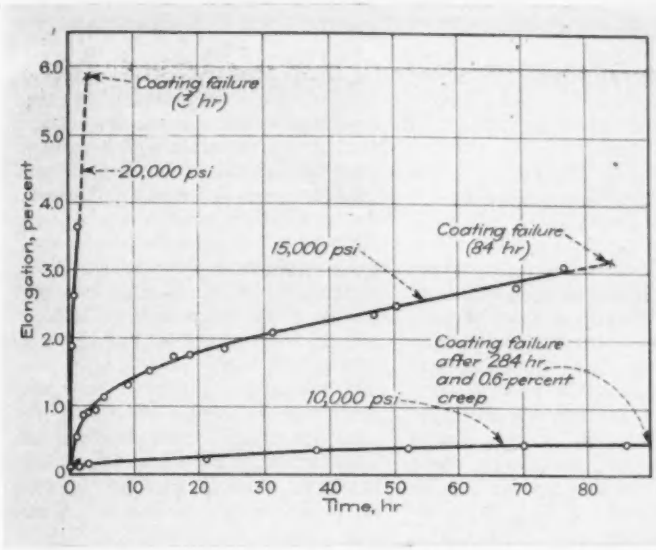
A-417 has been applied to several thousand gas-to-air heat exchangers for aircraft de-icing systems. It is possible, as indicated by field results, to extend the life of the Inconel parts as much as 100 percent. This material has a high thermal-shock resistance, allowing a coated part to be heated to incandescence and quenched in water without ruining the ceramic. Slight bending or flexing does not cause chipping or separation.

One typical use for A-417 is on exhaust stacks and collector rings on internal combustion engines for aircraft. The coating is applied to the rings both inside and out. Results have been excellent to date.

3. In an attempt to improve ease of application, coating A-417 was again modified by utilizing 10 percent copper oxide and 90 percent frit to produce A-520. This formulation is intended for use with austenitic stainless steels having a high coefficient of thermal expansion. Being not as refractory as A-417, however, it has not yet been used in commercial production.

4. In the case of coatings for molybdenum, one type that shows great promise is a chrome-frit coating, Table III, which contains both a glass phase and a metal phase. The glass phase vitrifies and seals the surface, developing adherence during firing. The chromic oxide-aluminum oxide admixture increases the refractoriness and also the imperviousness.

Normal life for molybdenum coated components is very short—on the order of one hour, Table IV; at lower temperatures (1,600 to 1,800 F) and low levels of stress, the life is much longer, Fig. 5. Molybdenum pitot



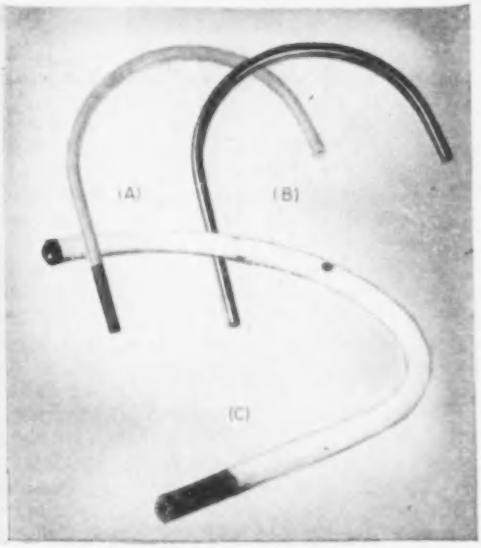


Fig. 5—(Left) How loading affects deterioration of molybdenum specimens dipped with NBS coating M-39-13. Test temperature was 1,650 F. Fig. 6—(Right) Uncoated (A) and coated (B) molybdenum pitot tubes for instruments. Uncoated specimen oxidized rapidly; coated tube (C) withstood 45 min. of operation in the blast of a ram jet engine at 3,000 F.

Table V—Composition of Ceramic Coating for Ceramals*

Electrolytic chromium powder (−100 mesh), grams	800
Frit 331 (−100 mesh), grams	200
Florida kaolin, grams	50
Sodium pyrophosphate, $Na_4P_2O_7$ (saturated), ml	7
Sodium nitrite, $NaNO_2$ (saturated), ml	1.5

* National Bureau of Standards Coating A-479M

Batch Composition of Frit 331

Constituent	Parts by weight
Flint (silicon dioxide)	38.00
Barium carbonate	56.63
Boric acid	11.50
Calcium carbonate	7.14
Beryllium oxide	2.50
Zinc oxide	5.00
	120.77

Computed Oxide Composition of Frit 331

Oxide	Percent by weight
Silicon dioxide	38.0
Barium trioxide	6.5
Barium oxide	44.0
Calcium oxide	4.0
Zinc oxide	5.0
Beryllium oxide	2.5
	100.0

tubes for instruments, shown in Fig. 6 were coated with NBS material and have withstood a gas temperature of 3,000 F for one hour, which was sufficiently long to obtain necessary test readings but far short of even minimum requirements for aircraft structural components, although an improved chromium frit casting has been developed by NBS.

Results have demonstrated that short-time protection of molybdenum in oxidizing atmospheres at gas temperatures up to 3,500 F is possible. Even such limited duration of protection meets certain current service requirements for other expendable items.

The following conclusions are believed justified from the study of chromium-type coatings for the protection of molybdenum:

- Frit, when used in conjunction with the chromium, gives coatings with considerably better durability than similar coatings containing no glass.
- Optimum protection at 2,800 F is obtained when the glass is diffused into the previously fired glass-free chromium coating structure through application of a seal coat.
- The resistance of the chromium-type coatings to cracking by thermal strain, or by rapid creep, is not particularly good but, because of excellent adherence and the tendency of the glassy phase to re-seal the fissures, cracking of the coating does not cause rapid failure but rather a weakening in the structure from which failure might begin.
- At 2,800 F and with no loading, the most durable coating protects molybdenum for about a maximum of 7½ hours.
- The maximum metal temperature at which chromium-frit coatings remain intact without flow in a high-velocity gas stream from an oxyacetylene torch is approximately 3,000 Fahrenheit.
- Maximum life achieved from

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coated specimens under load in an air atmosphere is on the order of 917 hr at 1,500 F (0.6-percent creep), 2,210 hr at 1,650 F (1.7-percent creep), and 3,275 hr at 1,800 F (1.2-percent creep). At any one test temperature, higher creep rates resulted in shorter coating life.

• The chromium-frit-type coatings show possibilities for practical use where long-time protection is nonessential at elevated temperatures (2,000 to 3,000 F metal temperature), or where the loading is such that creep rates will be moderate at temperatures in the range of 1,500 to 1,800 Fahrenheit.

5. Still another type of coating has been researched by NBS, this one for ceramals such as cobalt-bonded titanium carbide. Since many of these metal-ceramic combinations having good physical and mechanical properties may not have sufficient oxidization resistance, the function of the coating is to protect them at elevated temperatures.

A metal-ceramic coating was developed specifically for K-138, a Kennametal alloy containing 80 percent titanium carbide and 20 percent cobalt. This formulation, designated as A-479M, contains 80 percent by weight of chromium powder and 20 percent by weight of an alkali free frit, Table V. Chromium powder was selected for the metallic admixture because of (1) its high resistance to oxidization; (2) its thermal expansion, which closely matches that of K-138; and (3) its inherent hardness and resistance to abrasion. The frit or glass phase was considered desirable to give a coating that was less permeable to air and also to retard oxidization of the chromium particles.

This coating is prepared as a slip with clay as the floating agent, and is applied either by dipping or spraying. After drying, the coating is bonded to the ceramal by firing at 2,200 F for 10 min in a hydrogen atmosphere.

The fired coating is hard, smooth, and adherent. Microscopic examination of sections cut at right angles to the interface show the presence of a chromium-rich bond layer with numerous metal particles of the coating welded to the layer and to each other.

Oxidation tests in air for 200 hr at 1,800 F made with both coated and uncoated specimens showed that the effective thickness of an uncoated specimen decreased 0.0365 in. because of formation of oxide, while the coated specimen showed no significant decrease. (See Table VI and Fig. 7.) A thermal shock test made after the 200-hour oxidation test indicated that the coating was equally as resistant as the ceramal to thermal shock failure.

A deformation test, made on a bar-type specimen pressed from the coating material, showed that deformation of 1.3 percent was possible without cracking at a temperature of 1,500 F, thus indicating that the coating could be expected to creep with a ceramal turbine blade when operated at temperatures of 1,500 F. or above.

6. Finally, a base coating or attaching strain gages under severe temperature conditions, designated L6AC, is of considerable importance. Such gages are normally attached with a ceramic type cement which is baked on at a temperature of about 600 F. Unfortunately, this cement does not develop sufficient adherence to the alloy surface. To overcome this difficulty, the L6AC is first applied to the alloy as a thin base coat. This provides a strongly adherent, electrically insulating layer next to the metal. The small resistance-wire gage is placed on the L6AC surface and cemented to it with the baked-on ceramic. The resulting attachment is strong and adherent and has been used satisfactorily for the study of vibratory stresses in gas turbine parts at temperatures as high as 1,500 F.

Proprietary Coatings

Among the industrial concerns that have developed ceramic formulations is the Solar Aircraft Company. This concern, which has patent applications for several basic compositions and which is licensing the coatings under the general tradename of Solaramic, states that the following properties make them useful for metal protection at high temperatures:

(1) Low heat conductivity

(2) Good thermal shock and ex-

Table VI—Effect of Coating on Oxidation of Ceramals[1]

Coating	Coating thick., in.	Condition after 200-hr heating in air at 1,800 F	
		Loss in thick., in.	Surface appearance
A-479M (one coat)	0.0062	0.0009	Smooth surface, dark green color, some oxidation of K-138 at support hole
A-479M (two coats)	0.0087	0.0003	Smooth surface, dark green color, no evidence of oxidation of K-138, slight chipping of second coat at edges
Uncoated	0	0.0365	Moderately rough surface, dark gray color, some chipping and cracking of oxide layer, evidence of severe oxidation

[1]Determined after removal of oxide or coating layer by light sandblast.

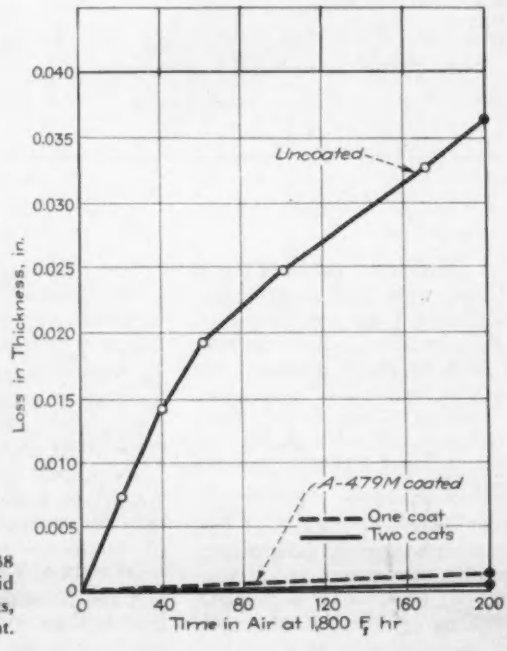

Fig. 7—Loss in thickness of Kennametal ceramal H-138 when exposed to 1,800 F for prolonged periods. Solid points were calculated from micrometer measurements, while others were calculated from gain in weight.

cellent oxidation resistance

(3) Resistance to fatigue

(4) Resistance to mechanical shock

(5) Good adherence and flexibility

The resistance of these coatings to thermal shock and to oxidation have been determined by test. Samples of coated and uncoated Type 321 stainless steel and of uncoated Inconel were heated for 45 minutes at 100 to 200 F above the proposed operating temperature, and then quenched for 15 min. in air. This was repeated through nine cycles after which the part was given a 15-hour soak at operating temperature. The entire cycle was repeated for 200 hours. The protected Type 321 stainless remained unchanged after approximately 200 hr exposure, while unprotected Type 321 lost almost 18 percent of its weight through oxidation. The uncoated Inconel gained some weight immediately because of oxide film formation, then held this weight throughout the test.

The fatigue life of metals is greatly enhanced by coating. Solaramic-coated welded samples tested at a deflection sufficient to produce 40,000 psi at the weld have withstood more than six million cycles, compared to an average fatigue life under 600,000 cycles for uncoated parts.

Solaramic coatings are formulated for a specific group of alloys. For example, a formulation for use on Type 321 stainless will satisfactorily protect other stainless steels of the AISI 300 series. It will not, however, produce a good bond on the low alloy or carbon steels.

Special coating compositions are also available to give some specific qualities not found in the basic formulations. Such properties as gall resistance and exceptional corrosion resistance can be obtained. Abrasion or gall resistant coatings are applied as a second coat over the basic coat.

Metals to be coated with high temperature ceramics should have:

(1) A slightly etched surface without rolled-in scale, pits or other defects.

(2) A low hydrogen and included gas content to prevent bubble formation and pinholes during firing.

(3) A high transition temperature —preferably above 1,600 F to prevent undue distortion during firing.

(4) The ability to develop upon firing a highly adherent oxide essentially insoluble in coatings and capable of existing for 15 or 20 min at 1,600 F or higher.

From the standpoint of design, the metals should also have good high temperature strength, fatigue resistance, ductility and weldability.

The highly alloyed metals are readily and effectively coated to obtain a longer service life. The stainless steels such as Type 321 can be coated to withstand service at temperatures normally resisted only by higher alloys such as Inconel and N-155.

Coating mild steels such as SAE 1010 and 1020 series presents three major problems. These are hydrogen evolution, oxidation and lack of structural strength. The main source of hydrogen is dissolved water in the frit. Oxidation of carbon in the steel produces volatile CO and CO_2 during firing. Both hydrogen evolution and oxidation result in blistering of the coat. Of course, the tendency of mild steels to warp and sag during firing presents dimensional difficulties.

Satisfactory coatings have been developed for mild steel that will insure good service life up to approximately 1,200 F. These coatings have been used successfully on SAE 1010, and 1012 and 4130 steels. They have a somewhat porous surface that allows gases to escape during firing before the coat is completely fused. The partially controlled atmospheres and special application techniques required for more refractory coatings that will protect low carbon steel at higher temperatures are not conducive to production techniques. However, work in progress at Solar is expected to overcome these difficulties.

Specifications for High-Temperature Coatings

The performance of the high-temperature ceramic coatings on low carbon steel in both laboratory and service tests led to the preparation of approximate specifications. These were issued during World War II as Army-Navy Aeronautical Specification AN-C-133 and as tentative specification AXS 1449 of the Army Ordnance Department. The principal requirements as written into these specifications are as follows:

(a) Thermal-Shock Resistance. The coating must withstand five quenches from a temperature of 1,200 F without visible damage, heat being supplied continuously to the underside of the quenched area. This test is performed on two coated, 18-gage tubes 6 in. long and 2½ in. in diameter, or on a section of exhaust tubing. A modified Meeker-type burner with a 90-degree elbow fitted onto the burner end is inserted into the test cylinder. The flame is lighted, and the burner is adjusted so that the temperature of the test area (as measured by a base-metal thermocouple with each wire welded separately to the outside of the steel tube) will pass through the temperature zone 1,185 to 1,215 F in 30 seconds. The flame is then extinguished and relighted. When the temperature again reaches 1,200 F, 25 ml of water at 70 ± 10 F is allowed to flow freely from the unconstricted large end of a 25-ml pipette onto the heated area of the cylinder between the thermocouple welds. This treatment quickly cools the affected area to a temperature below 212 F, as can be seen from the fact that before all of the water has left the pipette the surface of the specimen sustains a film of water instead of instantly vaporizing it as at the beginning of the quenching treatment. When the temperature again reaches 1,200 F, the quench is repeated until a total of five cycles has been accumulated.

(b) Oxidation Resistance. The protection of the metal against oxidation must be such that a 2½-in. by 3-in coated specimen of 18-gage enameling iron shall not gain in weight more than 0.03 g during 48 hr of heating at 1,200 F.

(c) Thickness of Coating. The thickness of coating must be not less than 0.002 in. nor greater than 0.003 in. on principal areas nor greater than 0.006 in. at beads.

Analogous specifications for the more refractory coatings for alloys in the A-417 and A-418 type have not yet been issued. Suitable test procedures are now under study by the armed services and Air Force in particular.

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4. Pitts, J. W. and Moore, D. G.—Ceramic Coatings for Prevention of Carbon Absorption in Four Heat-Resisting Alloys. NACA TN 2572, 1951.

5. Moore, D. G., Mason, M. A., and Harrison, W. N.—Relative Importance of Various Sources of Defect-Producing Hydrogen Introduced into Steel During Application of Vitreous Coatings. NACA TN 2617, 1952.

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Fig. 1—(a) Diagram of a metal ion concentration cell. The anode is the copper strip in the 1/10,000 normal solution of copper sulphate. (b) Oxygen concentration cell. The anode is the iron strip within the porous cup.

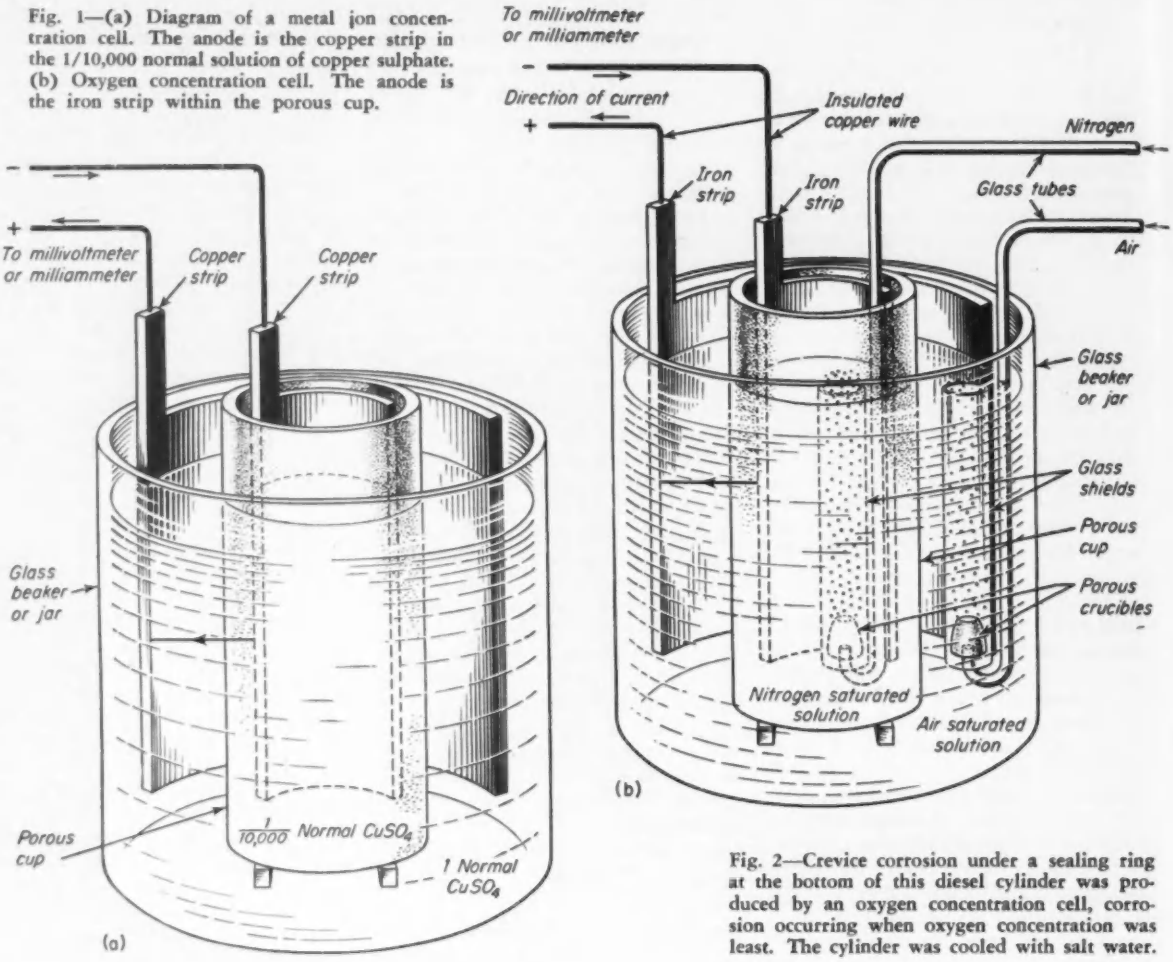

Fig. 2—Crevice corrosion under a sealing ring at the bottom of this diesel cylinder was produced by an oxygen concentration cell, corrosion occurring when oxygen concentration was least. The cylinder was cooled with salt water.

Corrosion Factors in

Article based on material supplied by F. L. LaQue and associates of the International Nickel Company, N. Y.

CORROSIVE ATTACK on metals is a function of many variables—not just the composition and concentration of the liquid or gas being resisted. Two major fields into which many of these variables fall are design and lubrication. The corrosion factors in these fields must be carefully studied prior to subjecting parts to corrosive service.

Proper design can contribute generously to resisting corrosion. Conversely, improper design can instigate or accelerate corrosion by setting up electrolytic action. Electrolytic cells are produced by the following:

(1) Presence of crevices.
(2) Velocity and turbulence of the corrosive fluid.
(3) Galvanic couples.
(4) Active—Passive surfaces.

The single step that might be taken by designers to most effectively reduce corrosion is the elimination of crevices. These are harmful for many reasons—some obvious and others not so apparent. The obvious reasons include: (a) trapping of corrosive liquids where they can concentrate and become more damaging; (b) delaying the drying of the metal within the crevices with the accumulation of corrosive substances along the edges.

The less obvious sources of corrosion associated with crevices involve the action of electrolytic concentration cells, Fig. 1, principally of the metal ion or differential aeration types.

In the metal ion concentration cell the anode (at which metal goes into solution) is located where the metal ion concentration is least. Corrosion will therefore occur just outside the

Fig. 2

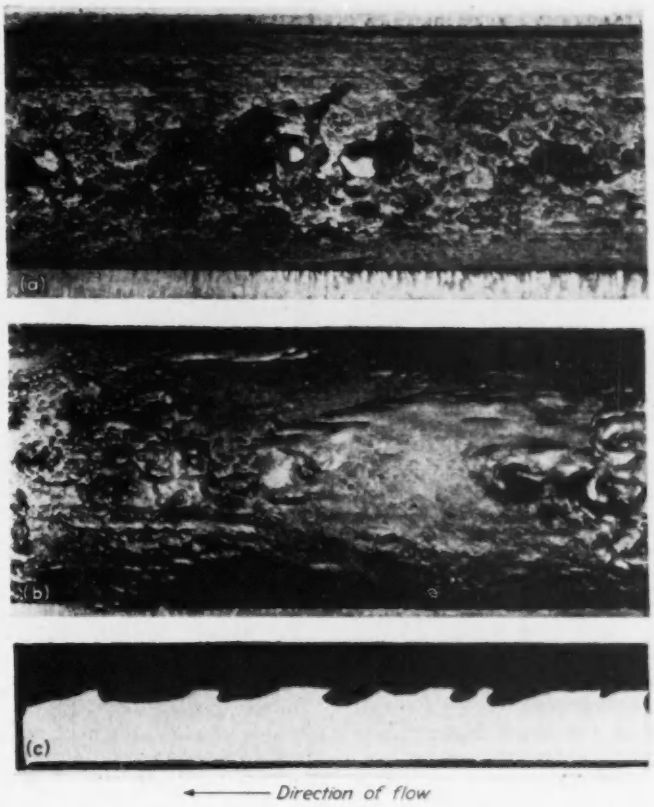

Fig. 3—Velocity effects on corrosion. (a) Condenser tube showing deposit attack occurring at low velocities or stagnant conditions. (b) Tube showing impingement attack at high velocities. Note the directional tendency of the corrosion attack. (c) Diagram showing impingement attack and erosion. The latter removes protective films and accelerates corrosion.

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Design and Lubrication

crevice where the metal ions are not able to accumulate.

In the oxygen concentration cell the anode is located where the oxygen concentration is least. Consequently corrosion will occur as shown in Fig. 2, within the crevice. In either case corrosion can be prevented by sealing the crevice or by eliminating it through use of butt joints or by redesign.

Velocity Effects

The velocity of a corrosive fluid can have marked effects on the rate and amount of corrosion. These effects occur at low velocities, high velocities or at high velocity differentials.

Under low velocity or stagnant conditions solid particles or discontinuous deposits or scales can lie on the metal surface. The area beneath these deposits acts as a crevice, and may become the anode of an oxygen concentration cell. Pitting, such as occurred with the condenser tube in Fig. 3 (a), will result.

Corrective measures that should be taken in design and operation of units where this condition exists are:

(1) Choose rates of flow high enough to prevent deposition.

(2) Where possible provide strainers to keep out objects that might become lodged in passageways.

(3) Arrange for periodic cleaning to remove corrosion accelerating deposits or scales.

With many materials, particularly the copper alloys used for heat exchanger tubes, there is a limit to the extent to which flow rates can be raised to keep surfaces clean. For example the velocity might be limited to 3 ft per sec for copper tubes, 6 ft per sec for Admiralty brass, 8 ft per sec for aluminum brass or 10 ft per sec for cupro-nickel. Very high rates of

flow may set up equally destructive metal ion concentration cells aggravated by galvanic action between filmed and unfilmed surfaces. Anodes will be located in areas where the velocity is highest and where corrosion product films are eroded or kept from adhering. Such mechanisms are largely responsible for the erosion or impingement attack, Fig. 3 (b) and (c), of condenser tubes.

This action is illustrated also by the corrosion pattern formed on disks whirled through sea water at high velocity. The distribution of corrosion, Fig. 4, indicates that at some critical degree of turbulence a slight increase in turbulence may cause a drastic increase in corrosive attack.

A high velocity differential from point to point is more destructive than a much higher uniform velocity. Systems and components should therefore be designed to minimize turbulence and to achieve maximum streamlining of flow.

In some cases, such as in complex piping systems, where it is impossible to avoid some local turbulence, materials should be chosen that have maximum resistance to turbulence effects. These erosion resistant materials will allow for much higher liquid velocities. Consequently smaller diameter piping can be used resulting in a cost and weight savings.

Materials that can be active or passive, principally the stainless steels, are particularly susceptible to oxygen concentration cell effects. These materials depend upon oxidizing conditions for maintenance of their protective passive films. A lack of oxygen will break down this passive film. The difference in potential produced by variations in oxygen concentration may not exceed 0.1 volt with ordinary iron but with stainless steel the difference in potential between active and passive surfaces may be as high as 1 volt and generally well over ½ volt. Thus the stainless steels are susceptible to corrosion in crevices into which oxygen cannot diffuse readily. This effect can be demonstrated by placing a rubber band around a piece of stainless so that it touches only the edges and then immersing the piece in a salt solution. Passivity will break down under the rubber band where the metal is shielded from oxygen. The active passive cell set up will accelerate the corrosion under the band to such an extent that it will cut a notch through the stainless steel.

Crevice corrosion of stainless steels Fig. 5 is also a problem where deposits are allowed to accumulate since passivity will soon break down beneath the deposit and pitting will result. Protection against crevice corrosion of stainless is afforded by

(1) Avoiding or sealing lap joints.

(2) Designing for conditions of flow that will prevent deposition.

(3) Cleaning equipment systematically.

(4) Where crevices cannot be avoided, selecting the type stainless most resistant to this action.

In selecting a sealing compound for joints or crevices care must be taken that the sealant does not form a crevice of its own along its edge. Petrolatum is a fairly effective crevice corrosion preventative. It does not induce corrosion on its own account as some other greases do and, as shown in Fig. 6, it has some anti-fouling qualities. Ordinary zinc-oxide has recently been found to be an effective sealant.

Stainless steels are very resistant to erosion and impingement attack at high fluid velocities so there is no danger of choosing too high a velocity to prevent settling of deposits.

Where crevices cannot be completely avoided types 316 and 317 stainless steel should be selected. These contain 2 to 4 percent molybdenum in addition to 18 percent chromium and 12 percent nickel. These alloys would apply also to salt water pump impellers where opportunities for crevice corrosion exist during shut down periods.

Galvanic Effects

There are still too many instances of improper design involving combinations of metals under circumstances that lead to serious galvanic corrosion. Of course it is rarely possible to use a single material for all parts of a complicated structure exposed to a corrosive environment. But in choosing the dissimilar metals to be used it is necessary to take certain facts and principles into account if difficulties from galvanic corrosion are to be avoided.

The first consideration is the relative positions of the dissimilar metals in the galvanic series as indicated in Table I.

Here it will be noted that the materials are divided into groups. Combinations of materials within a group are relatively safe compared with combinations from group to group. In any case, the opportunity for trouble increases with the extent of separation of the dissimilar materials in this series.

The stainless steels are listed in both their active and passive states. In environments where they normally are highly resistant to corrosion they will occupy their passive position. In borderline environments it will be prudent to assume that they may be active where their relative area is small and passive where their relative area is large.

The arrangement of metals in such a galvanic series indicates only the probable direction of the galvanic effect but not its magnitude. The extent of the action in terms of corrosion or

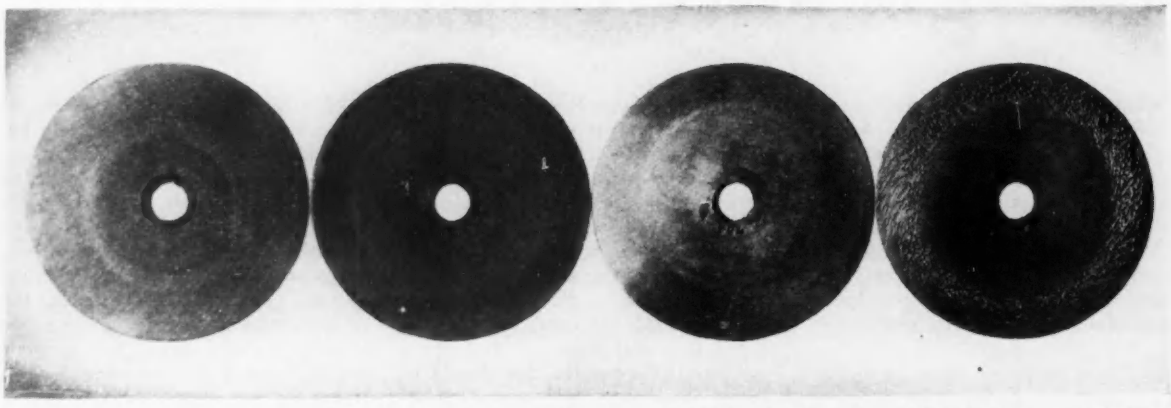

Fig. 4—Corrosion pattern formed on metal disks spun through sea water at high velocities. First, Admiralty brass; second, 90:10 Cupro-nickel, 0.7 percent Fe; third, 70:30 Cupro-nickel, 0.4 percent Fe; fourth, 70:30 Cupro-nickel, 0.05 percent Fe. The distribution of corrosion indicates the existence of a critical velocity or degree of turbulence for each metal.

protection will be determined by the amount of current that flows and particularly the current density. It is also influenced by what is called polarization of the anodes and cathodes.

For the present purpose, polarization can be defined as the drift of the initial potentials towards each other with a consequent reduction in the driving force of the galvanic cell resulting from passage of the galvanic current. The rate of this drift is determined by the current density, by the reaction characteristics of the metals and by the conditions of exposure—ordinarily high aeration and velocity retard polarization drifts and thus favor greater galvanic action.

What is bad is a combination involving a small anode and a large cathode since the anodic current density will be high and the cathodic current density will be so low that there will be little polarization of the cathode to reduce the galvanic effect. For instance, if steel plates are joined by copper rivets the area of the copper cathode would be very small and that of the steel large so the galvanic effect on the latter would be negligible. If copper plates are joined by steel rivets the high ratio of cathode area to anode area would produce a high anodic galvanic current density and cause severe corrosion of the steel.

All metals do not polarize equally and thus can have different galvanic effects independent of the open circuit potentials that can be measured. This is illustrated in Fig. 7 by a comparison of the cathodic polarization of copper and titanium in flowing sea water. It will be observed that titanium polarizes much more readily than copper and that a cell made up of steel and titanium should reach equilibrium at a lower current density than a cell of steel and copper and thus cause less galvanic corrosion of the steel. When more is known about the polarization characteristics of metals under more environmental conditions it can be expected that the choice of one combination over another for a particular service may be influenced greatly by such polarization properties.

It should be noted that certain aeronautical specifications that presume to distinguish between safe and unsafe metal combinations solely on the basis of open circuit potentials have a very unsound and unscientific foundation. This disregards the all important polarization phenomena and associated area effects just discussed.

Since it is the current that causes galvanic corrosion, anything that will reduce the current will reduce galvanic action. Thus, increasing the resistance of the galvanic current will be helpful. At the extreme, complete electrical insulation of the dissimilar metals will reduce the galvanic action to zero. When this is not possible the use of protective coating and insulating tapes will help.

In the atmosphere, galvanic action will not extend very far from the line of contact of the dissimilar metals because of the high resistance of the thin films of electrolyte that can form. This is illustrated by the combination of steel fastenings in magnesium shown in Fig. 8. The action is not likely to extend more than about $\frac{3}{16}$ in. from the line of contact. If this space is occupied by an inert material such as a plastic washer or by some metal galvanically neutral to or more compatible with both the fastening and the plate, the galvanic effect can be materially reduced or eliminated.

Where lap joints are involved the use of insulating tapes impregnated with protective coatings will serve to keep liquid from between the faying surfaces and if the tape or coatings should extend $\frac{3}{16}$ in. or so from the edge of the lap the galvanic effect will be negligible.

Caution must be exercised in the use of protective coatings to control galvanic corrosion. If the anodic metal is coated, it is essential that the coating be 100 percent continuous and suffer no localized deterioration in use. Otherwise, all the galvanic action will be concentrated on the small areas exposed at breaks in the coating.

A better practice would be to apply the coating to the cathode and leave the anode bare. Small breaks in the coating on the cathode can be tolerated

Table I—Galvanic Series of Metals and Alloys

Corroded End (anodic, or least noble)
Magnesium
Magnesium alloys
Zinc
Aluminum 2S
Cadmium
Aluminum 17ST
Steel or Iron
Cast Iron
Chromium-iron (active)
Ni-Resist
18-8-Chromium-nickel-iron (active)
18-8-3 Chromium-nickel-molybdenum-iron (active)
Lead-tin solders
Lead
Tin
Nickel (active)
Inconel (active)
Brasses
Copper
Bronzes
Copper-nickel alloys
Silver solder
Nickel (passive)
Inconel (passive)
Chromium-iron (passive)
18-8 Chromium-nickel-iron (passive)
18-8-3 Chromium-nickel-molybdenum-iron (passive)
Silver
Graphite
Gold
Platinum
Protected End (cathodic, or most noble)

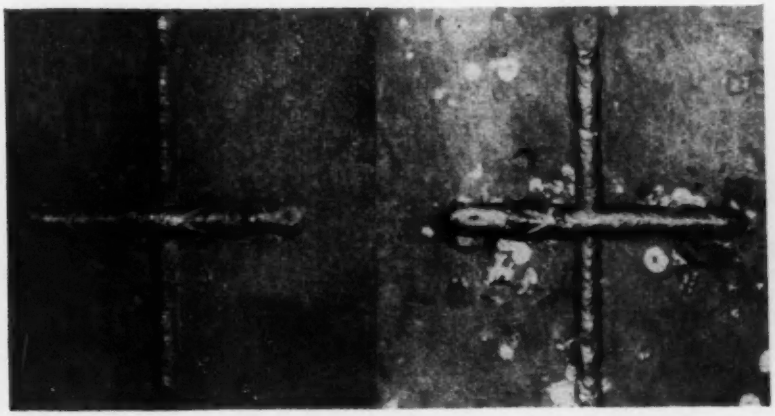

Fig. 5—Passivity of stainless steel will break down beneath deposits. Where possible the liquid velocity should be kept high enough to prevent deposition. At right, low velocity or stagnant conditions have caused pitting beneath accumulated deposits.

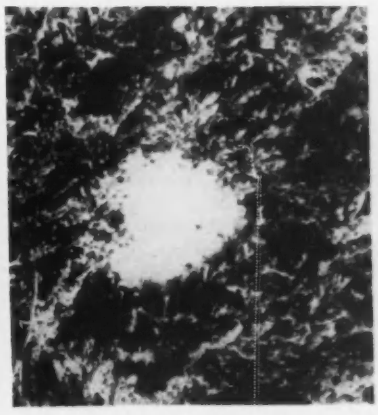

Fig. 6—Petrolatum is an effective crevice corrosion preventative with anti-fouling properties as the above smear shows.

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since they do not expose any substantial cathodic area to work on the relatively large anode. If the anode is to be coated, then the cathode should also be coated. This is much better than coating the anode alone.

Effects of Shelter on Corrosion of Steel

It has been established that the rate of corrosion of steel in the atmosphere is determined principally by the protective value of the rust that develops and to become protective, rusts must have a chance to dry occasionally. Thus, a partial shelter that interferes with the drying action of the sun and the wind and the washing action of the rain will result in maximum corrosion.

For this reason tanks and other vessels with steel bottoms should be raised off the ground far enough to permit proper ventilation and drying and thus retard corrosion by permitting the development of more protective rust films.

This applies as well to the elimination of crevices in which moisture may be trapped in other structures such as vehicles and farm machinery. There is plenty of room for improvement in this respect also in automobile bodies where underbody corrosion is most severe on those surfaces that receive minimum ventilation or may even be flooded occasionally because of inadequate provision for drainage of rain or condensed moisture. A possible soluton to this problem might be to circulate warm air from the engine to those surfaces that otherwise might not experience adequate drying.

Lubrication and Corrosion

The nature of lubricants is such that ordinarily they are expected to retard rather than accelerate corrosion. From the standpoint of their possible corrosive characteristics most attention has been given to bearings, especially in internal combustion engines and steam turbines. Certain bearing materials, especially those high in lead and cadmium, are subject to appreciable attack by acids produced by chemical changes in the lubricants. The rate of this acid formation is governed by such factors as the nature of the oil, the temperature at which it is used and the catalytic effects of metals in the system—particularly iron and copper.

In studying the corrosive characteristics of lubricants several more or less standard laboratory tests have been devised by which these several effects can be observed. Laboratory investigations have led to the development of lubricants so compounded as to be substantially non-corrosive to common bearing materials. An example is the addition of compounds calculated to prevent the formation of corrosive acids by oxidation or to inhibit their corrosive effects if present. The corrosion inhibiting additives are preferably supplemented by other compounds included to restrain the formation of engine deposits.

The same sort of study has also permitted the evaluation and guided the improvement of the corrosion resisting qualities of bearing materials and the use of such materials as indium to provide a corrosion resistant surface by a combination of plating and diffusion. As a result of all this, corrosion by lubricants does not seem any longer to be considered a major problem.

Corrosion is however a major factor in wear. Take for example the wear of the cylinders of automobile engines. As shown by the experiments of Williams and his associates in England a few years ago most of the wear in engine cylinders is actually the result of corrosion by the carbonic acid, organic acids, surfur acid, or hydrobromic acid, that come into contact with the cylinders when they operate below the dew point of the products of combustion.

Reduction of wear in automobile engines can be achieved by the following:

1. Designing the engine to operate with cylinder wall temperatures above the dew point of the products of combustion.

2. Using corrosion resisting alloys for cylinders—e.g. austentic cast iron or chromium plating.

3. Incorporating in the cylinder wall lubricant something to neutralize the acids in the condensate, inhibit corrosion by such acids or be able to cling to and preferentially wet the cylinder walls in the presence of relatively large volumes of condensate. From recent advertisements that have stressed the corrosion protecting qualities of automotive lubricants it would appear that considerable progress has been made in these directions already.

There is one more peculiar form of corrosion which still requires attention by designers and lubrication engineers. This is fretting corrosion

Fretting Corrosion

The term "fretting corrosion" has been applied to a peculiar form of deterioration that occurs on closely fitting machine parts when they are subject to vibration or other causes of almost infinitesimal slip between surfaces that for all practical purposes are in fixed relation to each other while the action is occurring—as in the case of components press fitted together.

One of the characteristics of fretting corrosion by which it may be identified is the appearance of a corrosion product which in the case of steel is a finely divided iron oxide principally Fe_2O_3 that looks like cocoa.

There has been a great deal of discussion about the mechanism of fretting corrosion and the parts played by chemical (corrosion) effects as distinct from physical effects. It is believed that the primary action is a physical one associated with molecular attraction between the closely fitting surfaces. Cycles of seizure and breaking away produce a detritus of minute particles that become heated as they are torn loose and are oxidized instantaneously to form the characteristic iron oxide corrosion product.

Apparently, the extent of damage is not influenced greatly either by the

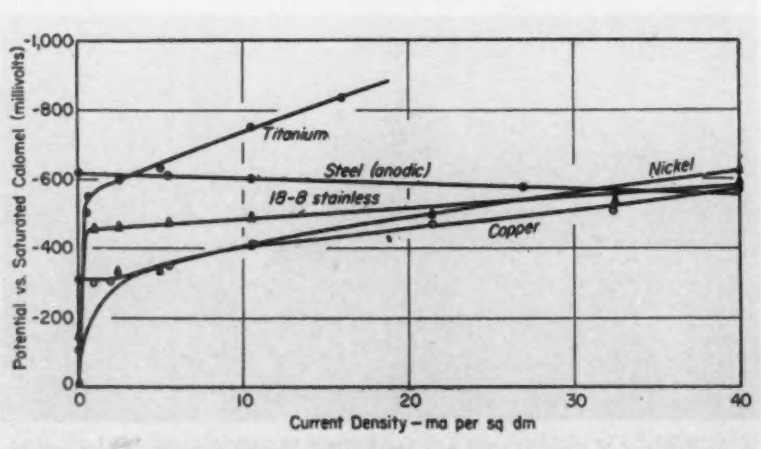

Fig. 7—Polarization of metals in flowing sea water.

Table II—Results of Fretting-Corrosion Investigation

Using Molybdenum Disulfide MoS_2 As Inhibitor

Method	Surface condition	Average number of cycles for first evidence of fretting corrosion	Observation of contact area during and after experiments
	Steel ball against glass flat		
..	Clean	1–30	Instantaneous fretting corrosion
1	MoS_2 dusted	72,000	MoS_2 formed smooth bearing surface then rubbed away
2	MoS_2 rubbed	21,600	MoS_2 smeared thinly then rubbed away
3	MoS_2, water and aerosol	21,600	MoS_2 visible only in surrounding area
4	MoS_2 and oil	86,400	MoS_2 visible only in surrounding area
5	MoS_2 and grease	216,000	MoS_2 visible only in surrounding area
6	Bonded MoS_2	28,000,000	Coating formed smooth bearing surface then brown stain appeared
	Steel flat against steel flat		
..	Clean	100	Immediate fretting corrosion
1	MoS_2 dusted	100,000–160,000	Dry red oxide and stain
4	MoS_2 and oil	700,000–760,000	Brown-black debris and spotty surface failure and stain
5	MoS_2 and grease	1,560,000–1,620,000	Brown and black debris and spotty surface failure and red stain
6	Bonded MoS_2	9,832,000–9,883,000	Smooth shiny bearing areas formed then brown powder appeared

intensity of pressure or the frequency of slippage—though some slip must occur.

Soft materials show more tendency to seize and less tendency to produce corrosion debris than hard materials. Stainless steels as a class are particularly susceptible to this kind of damage, though the hardened varieties have been found to be desirable in some instances.

The higher the initial surface finish, the greater is the severity of fretting corrosion. Also, attack on surfaces finished to the same degree is greater than where there is a difference in surface finish. Grit blasted surfaces have performed better than smooth surfaces—evidently as a result of a sort of keying effect which reduced slip.

Ordinarily lubricants have not been particularly reliable for preventing fretting corrosion. Best success with oils has been had when one of the parts was nickel plated.

In view of the nature of the deterioration process it would seem that the principal function of a lubricant would be to prevent the seizing that must precede the tearing away of the minute particles of metal. This would be more important than acting to exclude oxygen to prevent oxidation of particles after they have been torn loose.

The preferred oils have been low viscosity fluid lubricants with strong adhesive and extreme pressure properties and high resistance to oxidation. It also has been recommended that the contact areas be kept submerged in the lubricant.

Some excellent work in studying the nature and prevention of fretting corrosion is being carried out at the NACA laboratory in Cleveland. In studies of lubricants Table II molybdenum sulfide properly applied has appeared to be superior to all others.

Finally the writer understands that there is one peculiar relationship between lubrication and corrosion in connection with extreme pressure lubricants. Here the proper functioning of the lubricant appears to require that some attack of the metal by the lubricant must occur so as to yield a surface condition that reduces friction.

The field of corrosion in design and lubrication covers so much territory that it has been necessary in this article to select only some features of interest and concentrate on them.

Much savings can be realized and many failures prevented by a thorough study of these factors by design engineers.

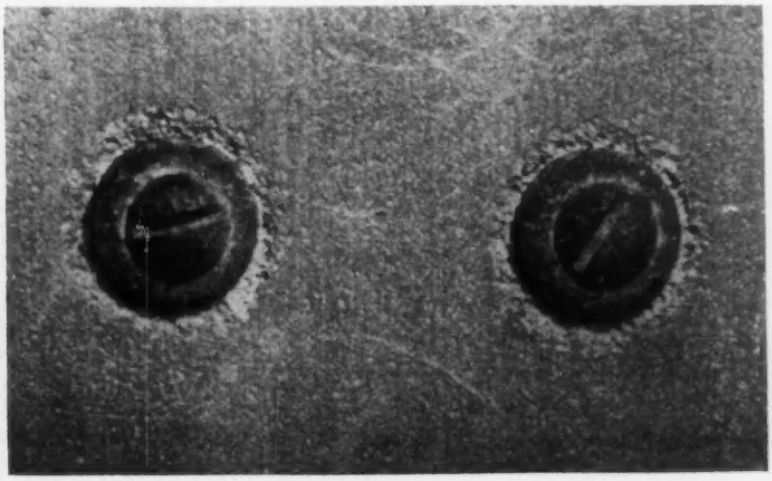

Fig. 8—Localized galvanic corrosion of magnesium around bare steel fastenings.

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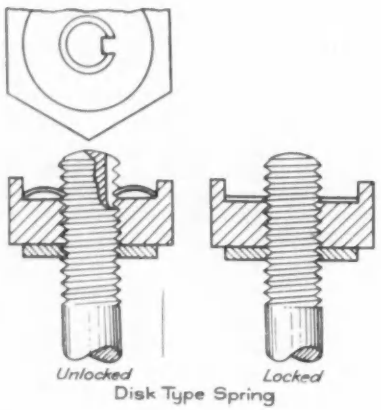
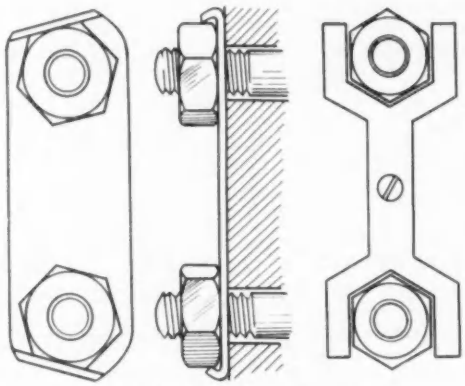
Various Methods of Locking

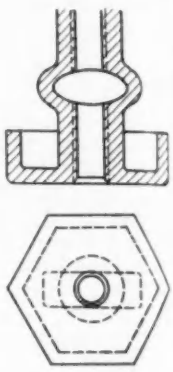
Locking devices can generally be classified as either form or jam locking. Form locking units utilize mechanical interference of parts whereas the jam type depends on friction developed between the threaded elements. Thus their performance is a function of the torque



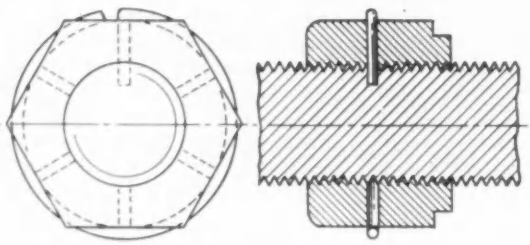
Disk Type Spring



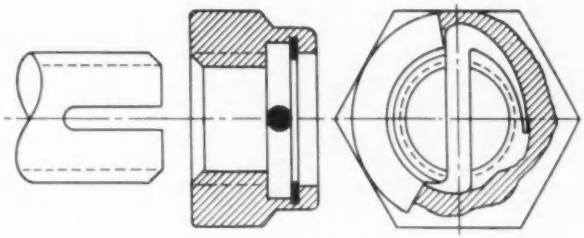
Double Formed Elements



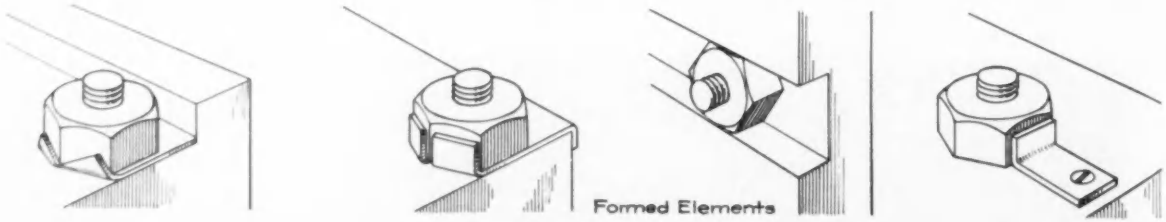
Sheet Metal Nut



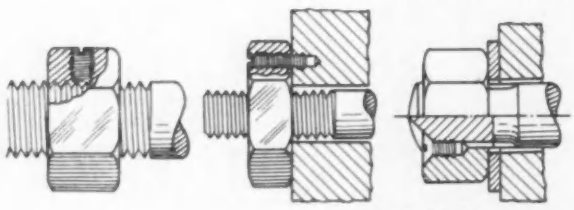
Spring Clip



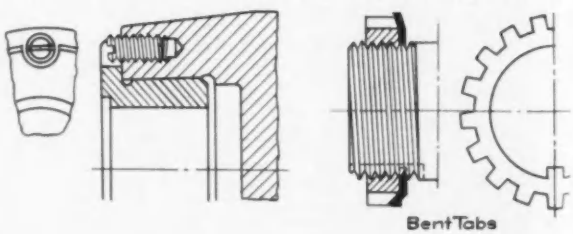
Ratchet Type Nut



Formed Elements



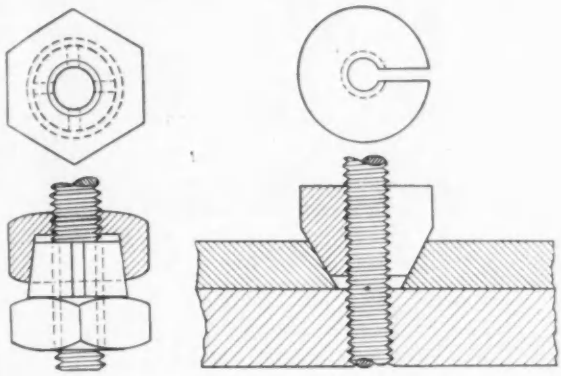
Ways to Use Setscrews



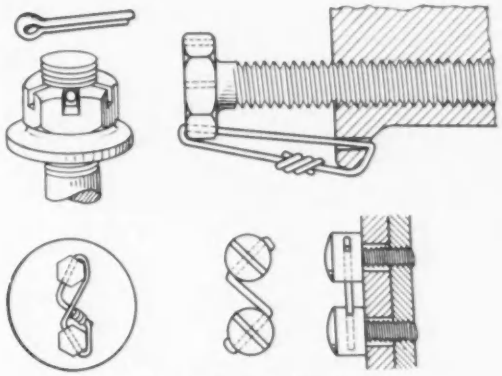
Bent Tabs

Threaded Members

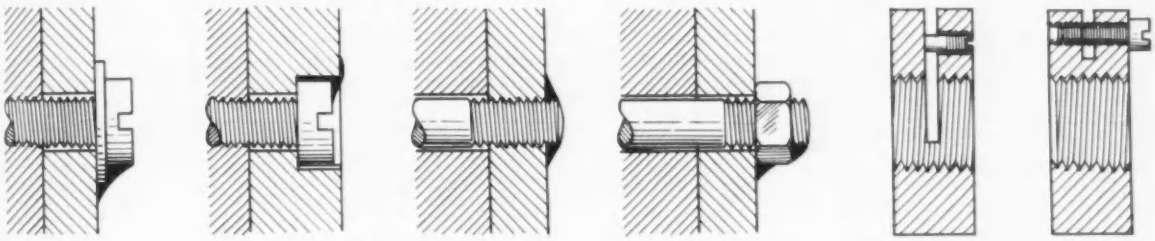
required to tighten them. Both types are illustrated below. For typical commercial locknuts, see the Reference Book Sheets, pages 205 and 207 of this issue. Credit is given to Frederico Strasser, Santiago, Chile, for much of the data shown.



Wedge Action

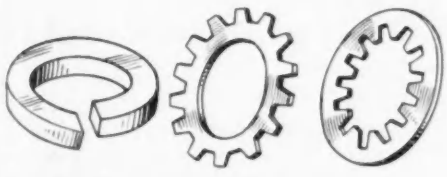


Cotters and Safety Wire

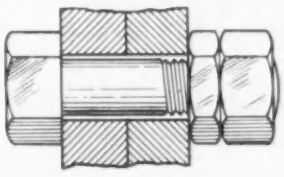


Cement or Solder

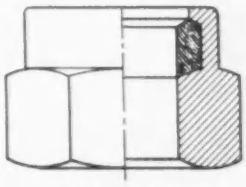
Split Nuts



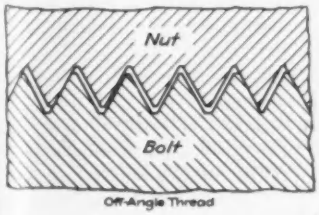
Spring Lock Washers



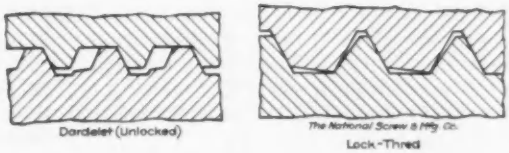
Jam Nuts



Fiber Inserts



Off-Angle Thread



Self-Locking Threads

Tapered Washer

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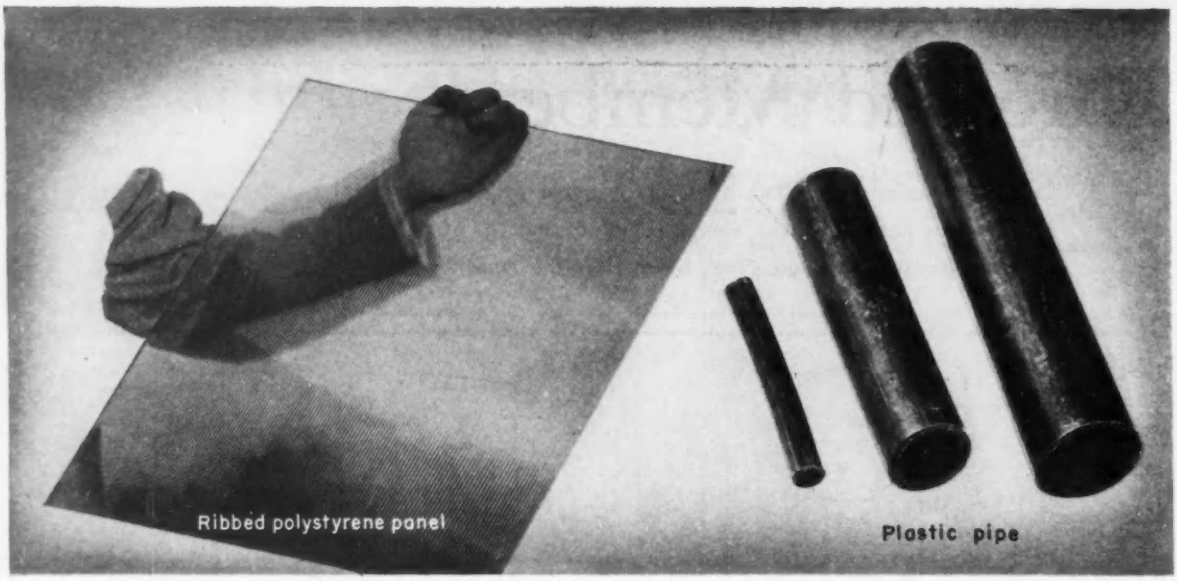


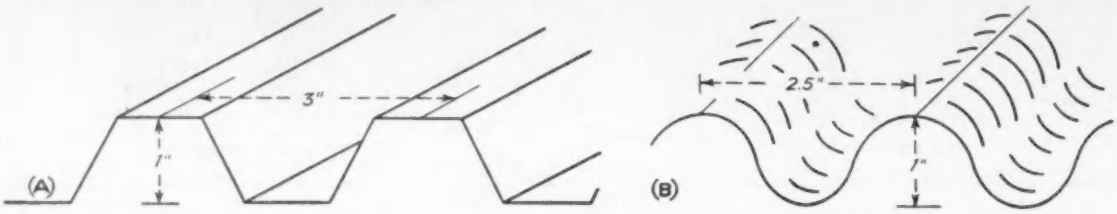


Fig. 1—Two types of corrugated sheeting (A) and (B) that might be produced by extrusion. There are many applications for this type of product. Light weight, low cost, and chemical inertness are some of the advantages of extruded plastics for this and other products pictured above.

Extruded Plastic Parts

R. S. PERKINS
Chemical Division
General Electric Company

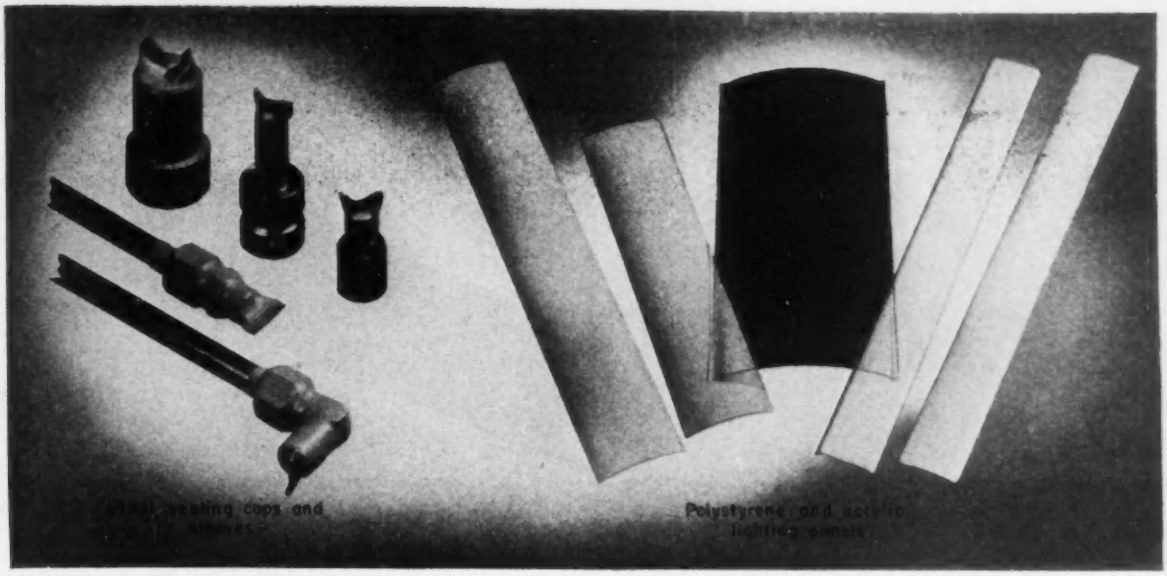
COMPARED WITH CASTING, laminating, and compression, extrusion, and injection molding, extrusion is the recommended method of producing plastic parts when (1) the cross section or length of the part is such that it does not lend itself readily to other methods of molding; or (2) the higher production rates, lower tooling costs, and resultant lower part prices make the process especially attractive for fabrication of large quantities.

Low piece cost results not only from the fact that a shape can be formed in a continuous length and cut-off to the desired dimensions, but also that the cost of an extrusion die rarely exceeds $400. Thus, die cost is a small portion of the total unless an extremely complex cross section is desired and intricate and exact tooling is necessary. While there is a set-up charge to cover the start of a production run and the resultant waste and spoilage, this usually is small. The larger the order, the less is the set-up charge per piece, inasmuch as it remains the same for any order regardless of size.

Post extrusion fabricating operations on extruded products to achieve effects that cannot be incorporated in die structure can at times be the most expensive portion of the parts price, due to the necessary tooling and labor to achieve the finished product desired. Actually, finished piece cost depends primarily on three factors:

1. The number of added operations to produce the finished article, such as drilling, slotting, punching, or stamping.
2. Tolerances required.
3. Materials cost.

In one instance, the material cost may be as low as 20 percent of the finished parts price, and in another, as much as 85 percent of the finished parts price. For purposes of rough estimating, the designer can consider material cost as approximately 55 to



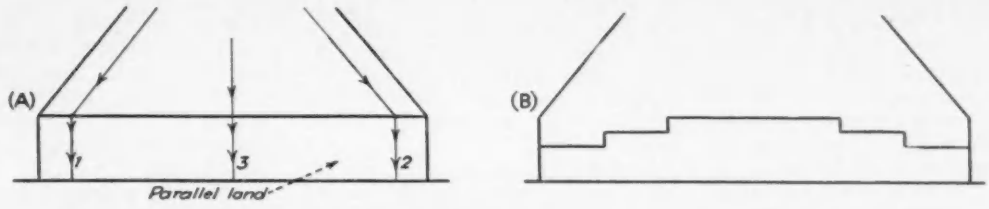


Fig. 2—Incorrectly designed die (A). Rate of flow will be faster at points 1 and 2 than at 3. The same die can be redesigned for correct flow, as shown in (B) by shortening the parallel lands to equalize flow at all points. Frequently, some development work is required to obtain satisfactory die operation.

Flexibility and low cost, as represented in applications such as these, account for the present industry interest in extruded plastic parts. Many basic compositions can be formed, including nylon, silicone, polystyrene vinyl, and the cellulosics. The author outlines current practies in production and techniques for use.

60 percent of finished parts price, assuming that no extraordinary and difficult fabricating operations or tolerances are necessary. However, where an undue amount of finishing operations are involved, the net result would be that the ratio of material cost to parts price would markedly increase. As in any material procurement problem, the size of the order affects the price from the standpoint of reduced raw material costs, set-up charges, and tool costs, which are all amortized over a greater number of parts.

To determine the amount of material involved per part, it is necessary to determine first the cross sectional area of the part, converting this factor to cubic inches per linear foot of extruded part, and then multiplying the resulting product by the weight per cubic inch of the desired material. The result is a weight of material per linear foot of extruded product and this, in turn, multiplied by the material cost per pound, equals the material cost per linear foot of extrusion (Table I).

Many different plastic compositions can be extruded. Materials such as the fluorinated ethylene polymers, nylon, and silicone rubber all offer extreme chemical inertness combined with heat resistance. Both polystyrene and methyl methacrylate panels are being extruded in varied shapes, designs, and colors, Fig. 1. Some have replaced glass in lighting fixtures and many advantages are being realized by this replacement. Some of those advantages are light weight, good light transmission characteristics and low maintenance costs, since replacement due to breakage is reduced to an almost absolute minimum.

Inasmuch as the specific gravities of modified polystyrene are approximately the same as regular polystyrene, these compounds are finding varied usage in applications where toughness and resilience are required, combined with lightness in weight.

The cellulosic materials have varied usage: extruded rod stock for tool

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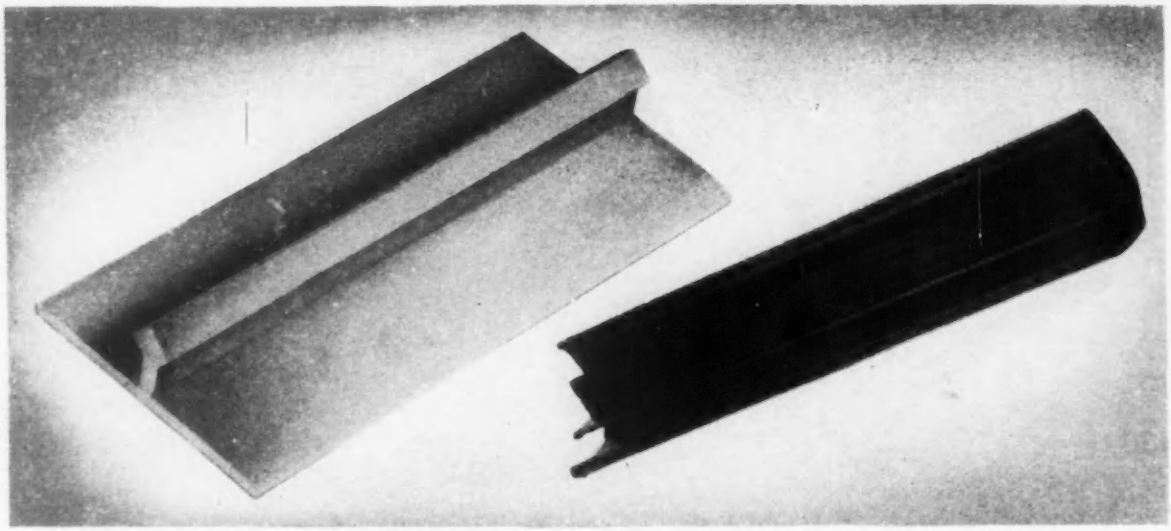

Fig. 3—Extruded structural shapes provide attractive trim on many commercial products. Widths up to 40 in. and lengths up to 10 ft and longer are practical from the production standpoint. Short sections of an inch or two are also produced.

handles, where high impact resistance is required; extruded pipe for aircraft water supply systems, and brine disposal in the oil well industry; as well as decorative trim for counters and displays, shelf edging, channels, and the like. The vinyl materials, of which there are many modifications, have varied usage, from novelty items to trim for luggage, electrical insulation, refrigerator door gaskets, and gaskets for automobile windows.

Gasketing materials in the flexible vinyl compounds have been coming into their own as a replacement for the rubber type gasket. The advantages realized are resistance to oxidation, aging, oils and fats. They retain their resilience, do not check or crack, are scuff-proof, and have solidity of color. Some of the newer postforming techniques for vinyl gasketing involve helical extrusions so that the piece is postformed continuously as it emerges from the extruder and while it is still in the plastic stage. By this procedure, the piece is permanently set to the curvature desired and will not tend to revert to its original shape after it has been in use for a period of time.

Extrusion Problems

All of the thermoplastic materials with the exception of nylon and polyethylene can be extruded and post formed by the same techniques with some modification in plasticizing temperatures, screw speed and occasionally screw design.

Nylon and polyethylene, due to their low viscosity, are probably the two most difficult materials to extrude, particularly where shaped extrusions are involved. Because of this low viscosity, the materials must first be shaped by the die aperture, then quickly chilled in water or some other suitable cooling medium before excessive "after flow" has taken place.

Modified polystyrenes or so-called high impact styrenes do not extrude with a particularly good finish as compared with that obtained from regular polystyrene, cellulosics, nylon or the acrylics, which possess good luster and smoothness. Consequently, if extruded parts are desired in modified- polystyrene, it must be remembered that the surface will be dull and have some tendency toward roughness. But this, by no means, affects its usefulness or durability.

Cellulosic materials, nylon and the acrylics are hygroscopic in varying degrees and must absolutely undergo a drying operation prior to extrusion. The presence of moisture in these compounds is evidenced by rough finish, bubbles and voids and what appear to be "fish eyes" or unplasticized particles. And frequently extrusion conditions are changed without avail in an attempt to compensate for a condition that can only be corrected by proper drying techniques and the complete removal of moisture and other volatiles that the compound might contain.

Postforming techniques of extruded products are playing an increasingly important part in producing shapes considerably more complicated than formerly thought possible by extrusion. These postforming techniques are quite similar to forming techniques in use in the steel industry where the forming is done on a continuous basis. Many of the seemingly complex designs in use today are extruded from a relatively simple die, then through the application of proper postforming techniques formed to more complex shapes.

Design Limitations

One advantage to extruded products is that any desired length can be obtained—short sections an inch or two in length or long sections up to 8,

Table I—Relative Cost of Plastic Materials

Material	Specific Gravity	Weight, lb/cu. in.	Price per lb
Polystyrene	1.05	0.038	$0.325
Methyl methacrylate	1.18	0.0425	0.70
Styrene copolymers	1.06	0.039	0.45
Polyethylene	0.092	0.0332	0.51
Nylon	1.15	0.042	1.85
Cellulose acetate butyrate	1.21	0.044	0.68
Cellulose acetate	1.33	0.048	0.63
Ethyl cellulose	1.14	0.0411	0.75
Vinyl	1.33–1.7 depending on filler	0.048–0.061	0.42

10, 12 and 15 ft. From a practical standpoint, however, the lengths of rigid extrusions should be limited to 8 to 10 ft due to packing and shipping problems encountered with longer lengths. On rigid extrusions, almost any widths can be achieved, up to 36 and 40 in. Development work is underway to produce still wider parts, for which applications are gradually being established.

Naturally, the wider the part, the greater the thickness must be, particularly where a certain amount of rigidity is a prerequisite. As a rule, the thickness should increase about 0.002 to 0.004 in. per in. of width. This roughly means that a 3 in. width in a thickness of 0.040 in. would, in a 12 in. width, be approximately 0.060 to 0.070 in. thick if sufficient rigidity were to be maintained.

As a rule, the larger the perimeter of the part, the more difficult it is to extrude because of the friction developed between the metal surfaces of the die and the plastic material. However, the larger the cross sectional area, the less force is required to overcome this friction. Consequently the difficulty of extrusion, although it increases with an increasing perimeter, decreases with an increasing cross section.

Since little technical data on extrusion die design has been made available, there are only rough rules of thumb for the extrusion engineer to follow. Therefore, every supplier of extrusion molded parts is faced with a certain amount of developmental work on every new product that is undertaken. Some required great amounts of developmental time and expenses, as evidenced by multi-color extrusions and by complex shapes such as gaskets, counter trim, edgings, and lighting panels. Others, such as simple tubes and small diameter rod stock required very little experimentation.

Table II—Comparative Commercial Tolerances for Extruded Plastics and Metal

Width, in.	Tolerances, in.	
	Plastics	Metal
0.125–0.25	±0.006	±0.007
0.25–0.5	±0.008	±0.008
0.50–0.75	±0.009	±0.009
0.75–1.0	±0.010	±0.010
1.0–1.5	±0.015	±0.012
1.5–2.0	±0.018	±0.016
2.0–4.0	±0.025	±0.024
4.0–6.0	±0.030	±0.034
6.0–8.0	±0.040	±0.044
8.0–10.	±0.050	±0.054
10.–12.	±0.060	±0.064
12.–14.	±0.070	±0.074
14.–15.	±0.080	±0.080

The matter of die correction to obtain proper balance of flow and achieve uniformity of thickness is often the most difficult and time-consuming operation of all, inasmuch as several trial runs have to be made before correct flow distribution is obtained. As can be seen from the accompanying sketch, Fig 2, on parts of large width, it is necessary to balance the flow within the die as material moving at points 1 and 2 has a longer distance to travel than at point 3. Consequently, with the longer distance, greater frictional forces are encountered and must be reduced by decreasing parallel land length.

Multi-colored extrusion is a rather specialized field and not all extruders are equipped for or inclined to enter it, as it is at present limited to the decorative trade, and novelty item trade. However, the possibilities of multi-colored techniques in the large rigid extrusion field are many, particularly for decorative panels.

The basic principle of multi-colored extrusion is the same as conventional extrusion except that a separate machine is required for each color.

The machines are set up in such a way that they all feed into a common die, suitably channeled to direct colors where needed. The materials eventually converge at a point just short of the die orifice where bonding of the different colors takes place and a sharp line of demarcation is maintained. In this respect the die design for multi-colored extrusion is rather tricky, as the colors would run together or blend if the converging point of the materials was too far back in the die.

Commercial tolerances of plastics extrusions that have been generally accepted by industry compare favorably with the commercial tolerances for extruded metal parts. The tolerances for both metal and plastics listed in Table II are almost identical for any given dimension.

Closer tolerances can be obtained, but only at the expense of higher part cost and lower production rates. In some instances where extremely close tolerances are required for extruded plastic rod and tubing, it is necessary to utilize a centerless grinding operation for finish grinding the product to tolerances of ±0.0005 inches.

Finally, sharp corners should be avoided, due to the weakening effect that they may have on the structural qualities of the part. Wherever ribs or fluting are incorporated into the design, they should be well filleted at the corners at no less a radius than one-half the cross section.

How Powder Metal Is Being Made

PRODUCERS ARE NOW USING three major methods to convert metals to powders for use in powder metal processing according to Samuel Bradbury of the F. J. Stokes Machine Company.

Chemical reduction is the most widely used method. Oxides of such metals as copper, iron, and tungsten are derived from ores by roasting or chemical means and are then ground to powder in a ball mill. Iron oxides are often heated in the presence of coal or coke to burn out the oxygen and create carbon dioxide. Copper oxides are usually handled in trays in a hydrogen atmosphere at temperatures on the order of 1,500 F.

Big advantage of this process is the fact that the resultant powder has good "green strength." Since particles of reduced oxides knit well together and form a good mechanical bond, parts have good strength after pressing and before sintering.

Atomizing is used for metals like lead, tin, aluminum, and brass that have relatively low melting points. In this process, the metal is melted and poured in a thin stream through a nozzle. As it emerges, the metal is hit with a high speed stream of air, gas, or water spray that creates a shower of tiny droplets that form tiny solid particles in the shape of either a sphere or a teardrop when they hit a collector. In a variation of this process, heated air and melted metal is drawn through an atomizing nozzle to form the powder.

Electrolytic deposition is a more expensive method of making powders but produces purer materials. Iron, copper and silver are often made with this technique. It's the same process as ordinary electroplating, but the platers want a spongy cathode instead of a solid coating of the pure metal. High amperage produces gassing that causes a powdery or brittle deposit.

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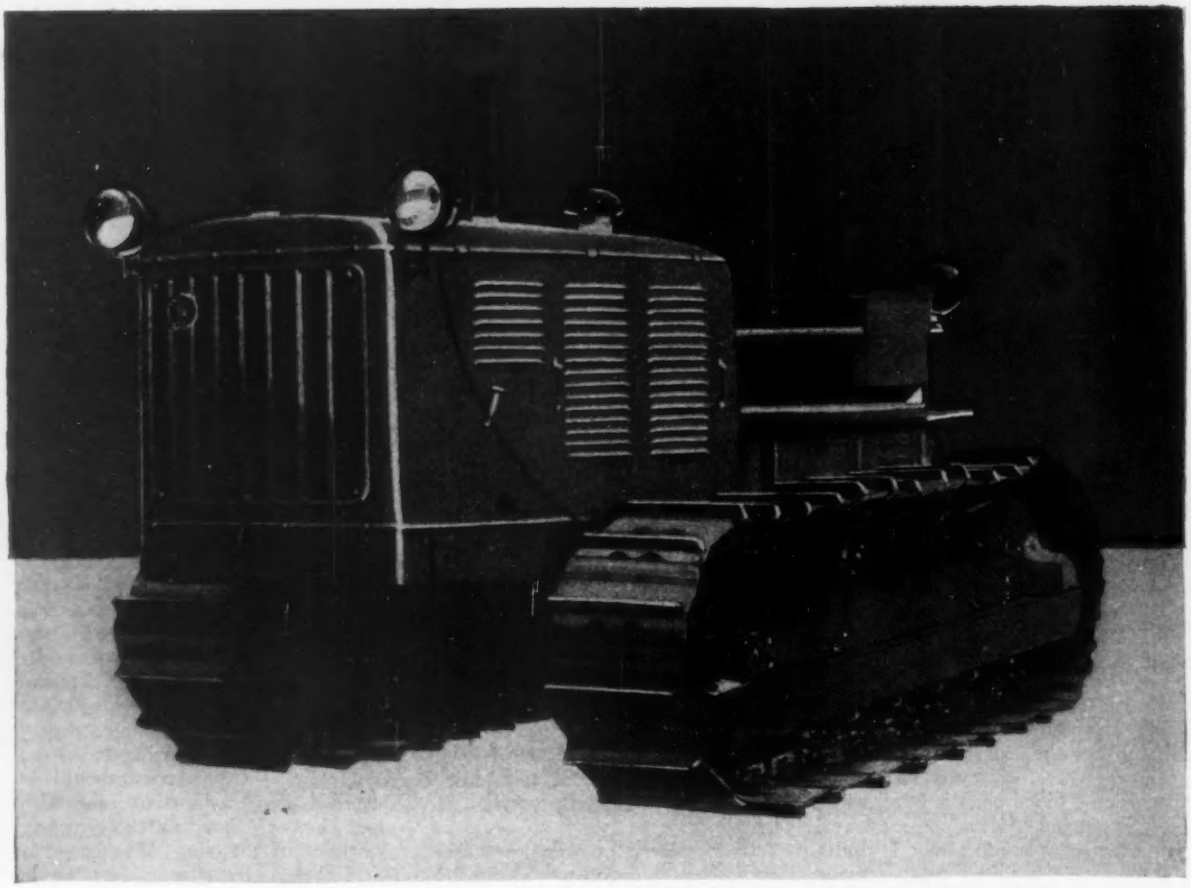


STALINETZ 80 closely follows the original Caterpillar basic design, but it has been completely redesigned, part by part, to conform to metric dimensioning, to fit Russian shop practices, and to use materials available to Russian engineers. Captured instruction manuals show that the Soviets have also copied latest U. S. design changes.

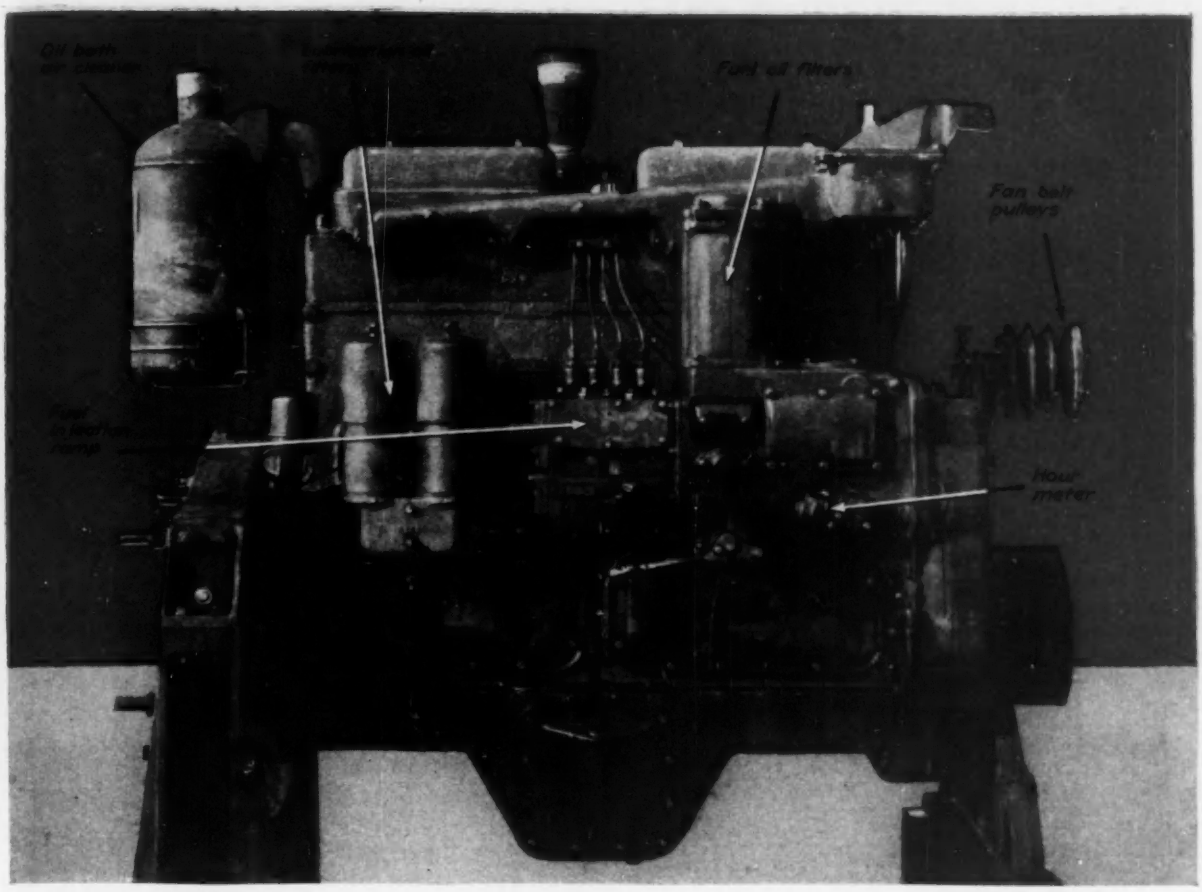
Russians Shun Frills on Stalinetz Tractor;

At first glance, Russian Stalinetz 80 Tractor is a perfect copy of the D7 Tractor built by the Caterpillar Tractor Co., Peoria, Ill., between February 1942 and March 1943. But the Soviets have injected their own design concepts in redesigning the Diesel D7 to conform to metric dimensioning, to fit Russian shop practices, and to use materials available to Russian engineers.

Caterpillar's research department prepared a detailed analysis of captured Stalinetz tractors which indicates that Soviet engineers are ingenious, not just imitators, and they are up to date on current design and production techniques.

The most significant difference between Russian and Caterpillar design is the finish of parts. Soviet engineers specify very rough finishes on all unimportant surfaces. But when a fine finish is essential to the function of a part, Russian finishes are every bit as good as American. In addition, the Russians allow larger tolerances for dimensions unless a part's function requires close tolerances. In this case, the dimensions are held as close, or closer, than American. Obviously, the Russians have the equipment and know-how to make precision parts, but they use them sparingly and only when precision is required for proper functioning.

Despite the comparative looseness of tolerances, sufficient control is exercised so that Russian parts are interchangeable. When Caterpillar started its analysis, the two captured tractors were in poor condition. The ma-



RUSSIAN ENGINE rebuilt by Caterpillar engineers looks identical to Cat D7 tractor engine except for roughness of exterior finish, which is not up to American standards. Bore of this engine is 145 mm instead of 5¾ in.; and stroke is 8.071 in. instead of 8 in., resulting in a reduced displacement of 1 cu in. per cylinder; but performance is not reduced.

Designed for Simple Low Cost Production

chines had been pierced by bullets, perhaps sabotaged; the engines were frozen and had been run without lubrication prior to their capture; parts were missing or had been pirated. However, Caterpillar was able to provide one complete engine for dynamometer testing by dissembling two engines and salvaging parts. The easy interchangeability suggests that tools, dies, and fixtures similar to Caterpillar's were used in Russian production.

Not a single Russian part is interchangeable with the Caterpillar part from which it was copied. Metric dimensioning is not the only reason, however, because even the internal parts of the Caterpillar fuel pump (made to metric dimensions originally) are not interchangeable with the Russian parts.

In metallurgy, the Soviets substitute more available chromium, nickel, or manganese in parts where American practice dictates high molybdenum content. They use heat treating practices such as flame hardening, induction hardening, and die quenching of bevel gears to get the same degree of hardness as is found in American counterparts.

The Russians appear to prefer steel castings to forgings or stampings, and the castings usually have a rough finish.

Caterpillar research engineers conclude that the Stalinetz 80 is a very satisfactory military tractor and is the best engineered of the foreign-made tractors that have been examined at Peoria. *(continued on next page)*

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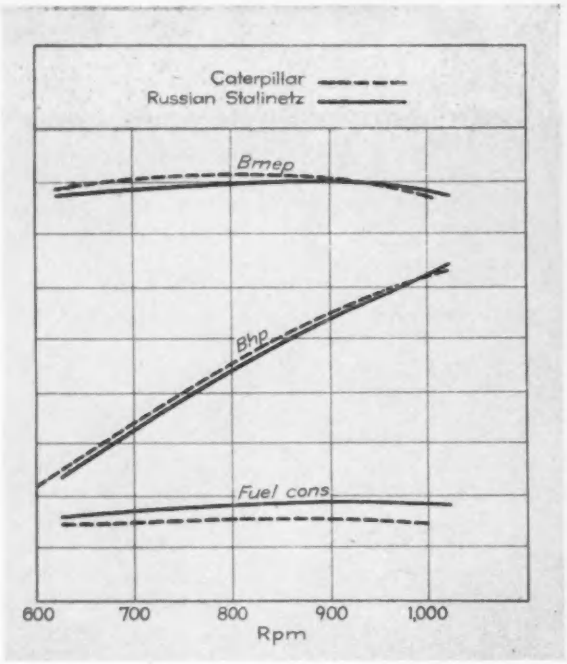
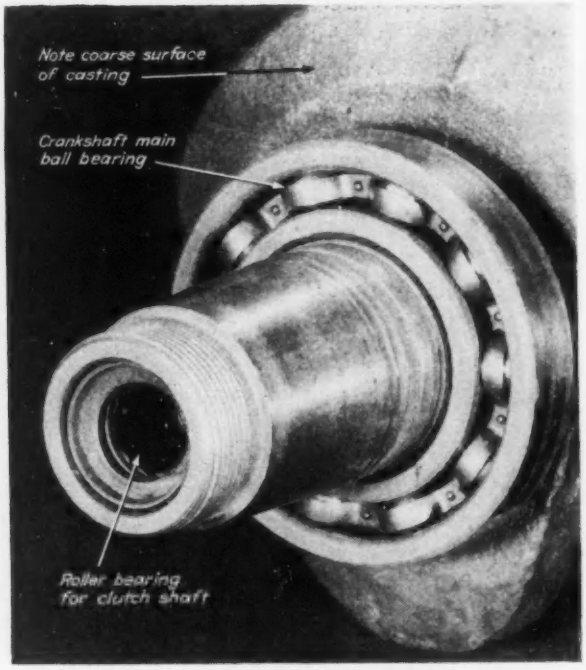
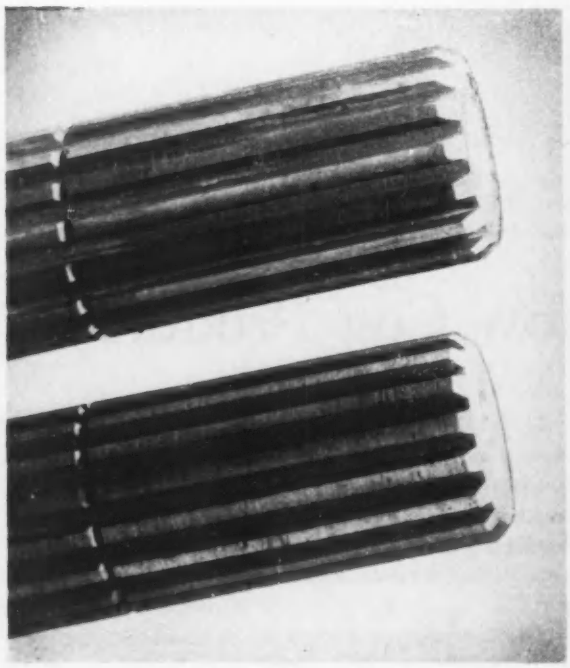
Stalinetz Tractor (continued)



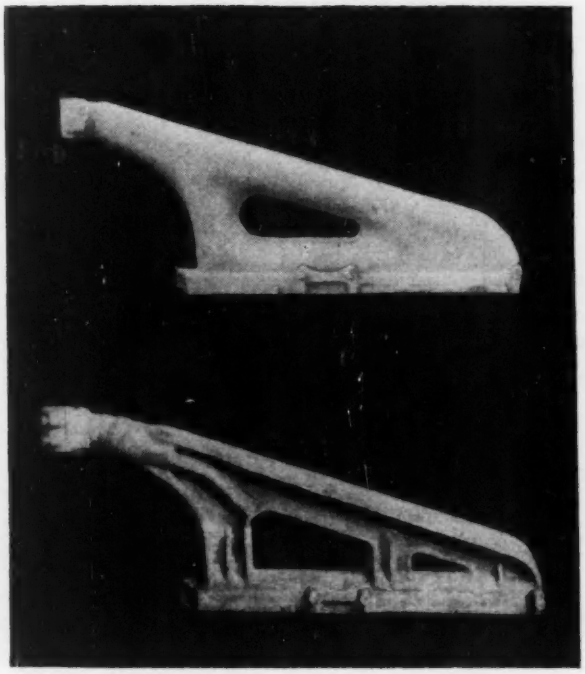
COMPARISON of lug performance. Stalinetz 80 engine performs as well as Diesel D7 engine, and its maximum output is slightly higher. Differences in fuel consumption at full load (shown here) are not significant; at part or lighter loads, Stalinetz fuel consumption is as good as D7.



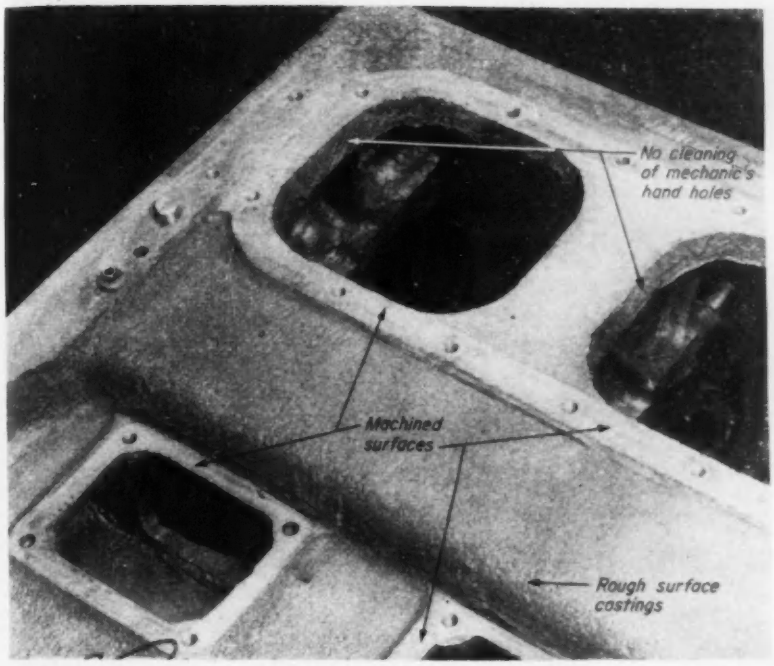
SIGNIFICANT ENGINEERING change in Russian starting engine crankshaft. Anti-friction bearings replace babbit type main bearings and improve cranking ability at low ambient temperatures. Recently Caterpillar has replaced the babbit with aluminum as the main bearing material.



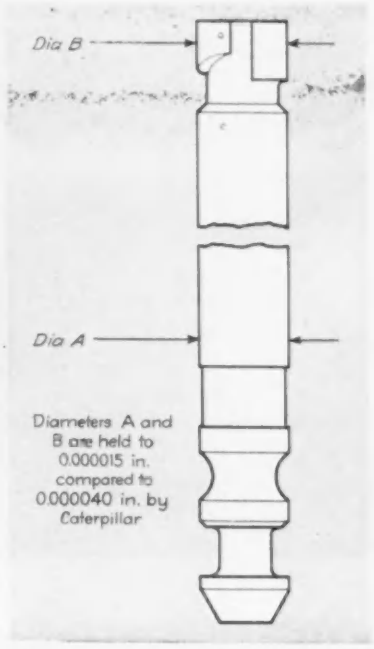
MINOR CHANGES in transmission top shaft prevent interchangeability between Stalinetz (lower) and D7 (upper). While there are the same number of splines, they are shaped differently. Notice the rough finish at top and bottom of splines on Russian shaft, but tool marks do not interfere with satisfactory performance.



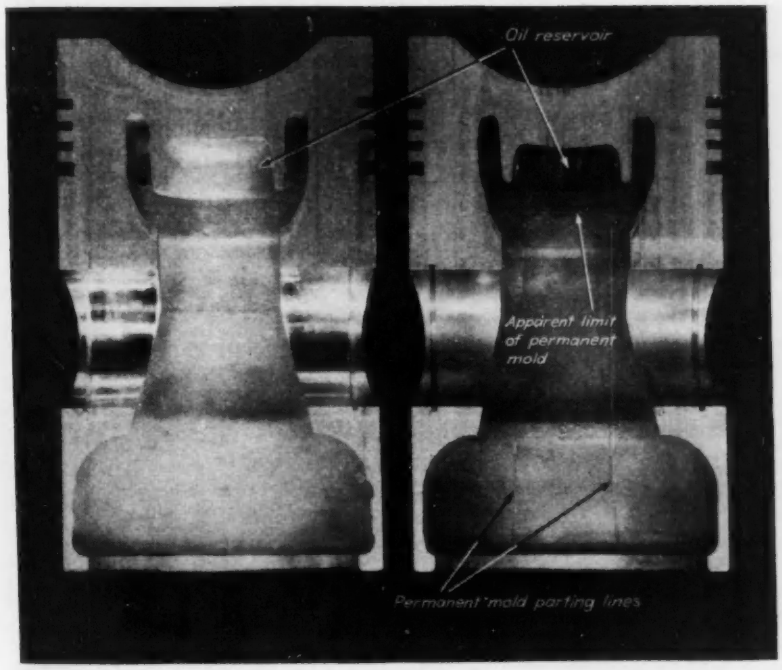
STEEL CASTING, (lower) replaces Caterpillar forged roller frame (upper). While appearance of forging is superior, either design is adequate for the function. Russian preference for castings may be based on a shortage of forging facilities and press equipment rather than on metallurgical reasons.



RUSSIAN CYLINDER BLOCK. Rough finish on castings is caused either by very coarse sand or poor wash practices on the molds. Note poor cleaning of holes through which bearing caps are removed. Machined surfaces provide adequate surface for good gasketing. Russians do not use paint seal on inside surfaces of crankcase to prevent loosened particles from contaminating oil.



RUSSIAN FUEL PUMP PLUNGER has same shape and contour as Caterpillar plunger but is not interchangeable. Lapped surfaces are held to closer tolerances than D7 plunger.



RUSSIAN PISTON casting technique. Stalinetz piston (right) was cast using a sand core only for the portions underneath the crater where the piston oil reservoir is located. Apparently, that core was set on top of a seven piece permanent mold core. D7 piston (left) was cast with a full sand core. The Russian piston is made of aluminum alloyed with large quantities of silicon and copper; D7 piston is aluminum alloyed with magnesium and no silicon.

RUSSIANS SURPASSED Caterpillar with the fabrication of the transmission shifter fork. Possibly because Soviet forging dies are newer, their forks (lower) are finished forgings.

(Continued on next page)

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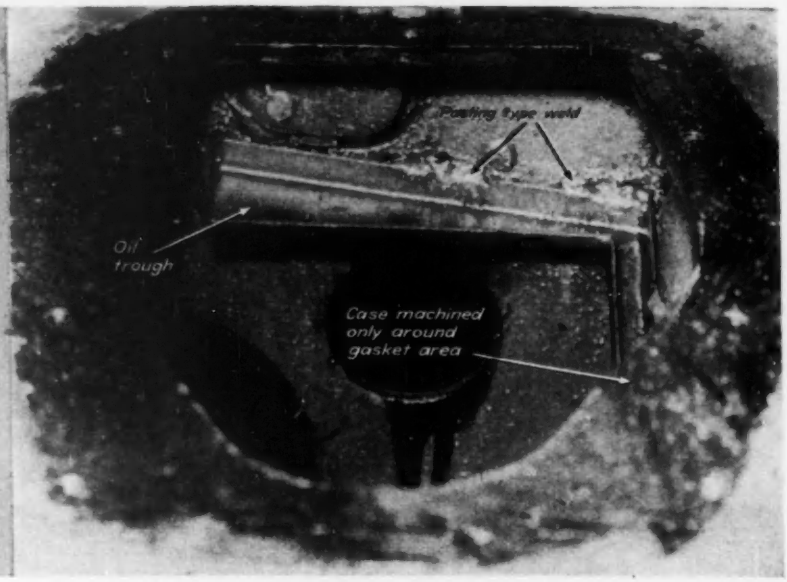
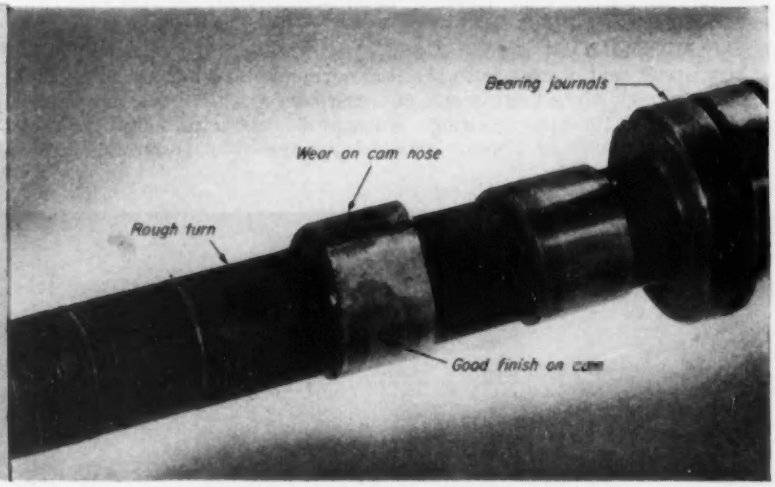
Stalinetz Tractor (continued)

BEVEL GEAR compartment in which steering booster fits (left). Russians added the oil trough, which carries oil picked up by the bevel gear over to a tapered roller bearing.

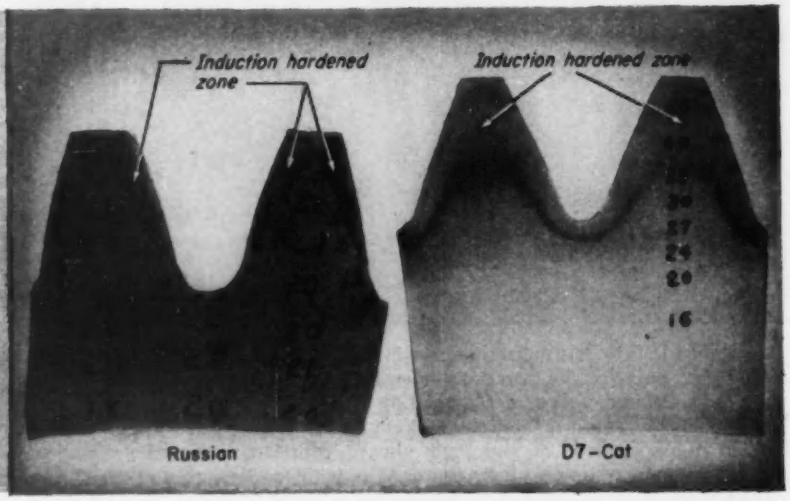
FINAL drive roller bearing (right). Russian (a) has different inside and outside diameters than D7(b). Also, it has 13 rollers instead of 12. A larger taper on the inner race makes the Russian bearing easier to assemble but more difficult to adjust the rollers within the narrow race path.

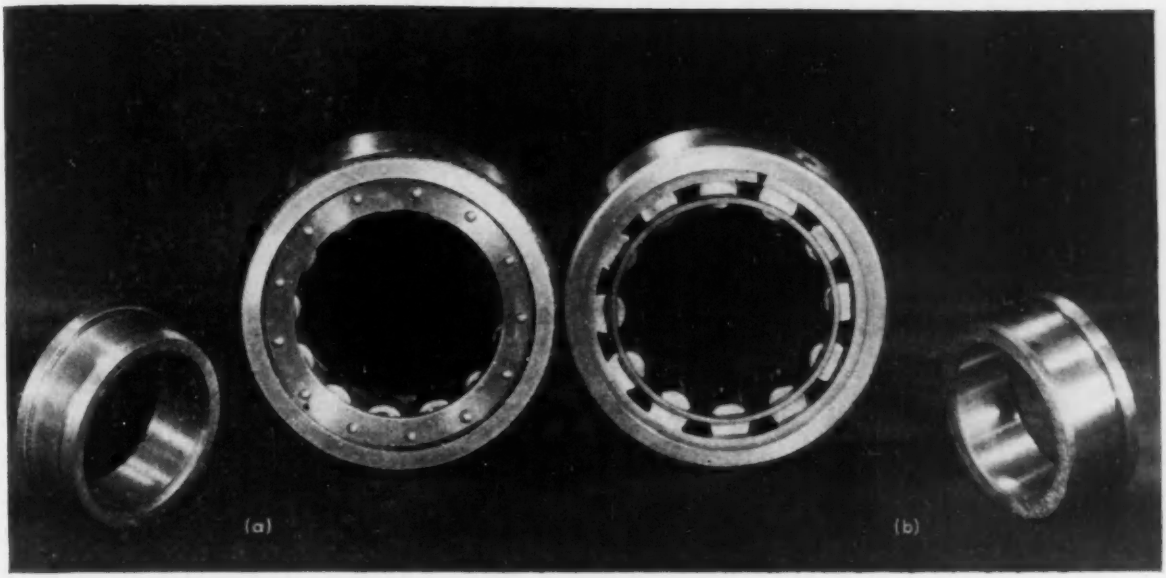


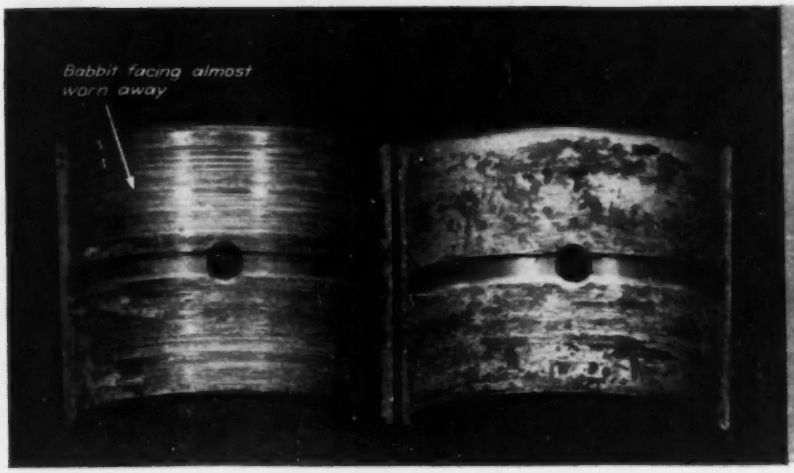
RUSSIAN CAM SHAFT has rough turn on unimportant areas, but cam surfaces and cam journal bearings have excellent finish, equivalent to that on D7 cam surfaces. Shaft is carburized to a full hardness of Rockwell C60. Wear on cam nose was caused by grinding action of dust and dirt present in the engine, not by improper heat treatment. This was excellent.



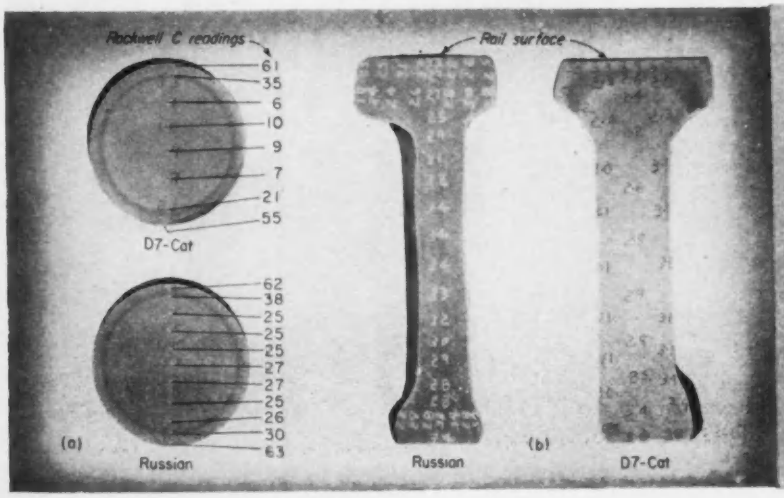
CROSS-SECTION of final drive bull gear. Induction hardness pattern of Russian gear does not extend all the way down each tooth, and the hardness is rapidly fading out at the pitch line. During Caterpillar induction hardening, the gear is spun within an inductor block so that surface hardness pattern extends below the root of the teeth. (Numbers show hardness.)







CONNECTING ROD bearings were in bad shape from improper maintenance, but composition was the same as in Caterpillar track-type tractors produced in 1940: bronze backed tin-base babbit. Russian wrist pin bushings are equivalent to Caterpillar SAE 64 bronze and their connecting rod bolts are practically the same alloys as those used by Caterpillar.



CROSS-SECTION of track pin (a). Both of these pins are induction hardened and good heat treating practice is evident. Russian pin has better uniformity than the D7 pin. (b) Cross-section of track link. Russian link is considerably lighter (about 1 lb each). At present, Caterpillar induction hardens the rail surface. The Russians do not, and ten years ago Caterpillar did not.

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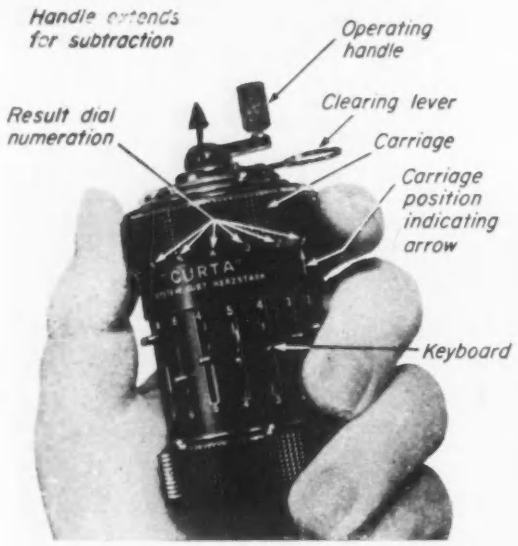
Miniature Machine



Carriage can be rotated into any one of six positions for multipliers of more than one digit. If indicating arrow points to 1 of result dial place numeration, the number set is transferred unaltered to the result dial; with arrow at 2, number is transferred 10 times; with arrow at 3, number is transferred 100 times, and so on. Turns are recorded in the counter dial accordingly, as 1, 10, or 100.

By using a single step drum to actuate successively each digit setting of the machine instead of an individual drum for each setting, Contina, Ltd., Mauren Liechtenstein has made the Curta Calculator small enough to be handheld during operation.

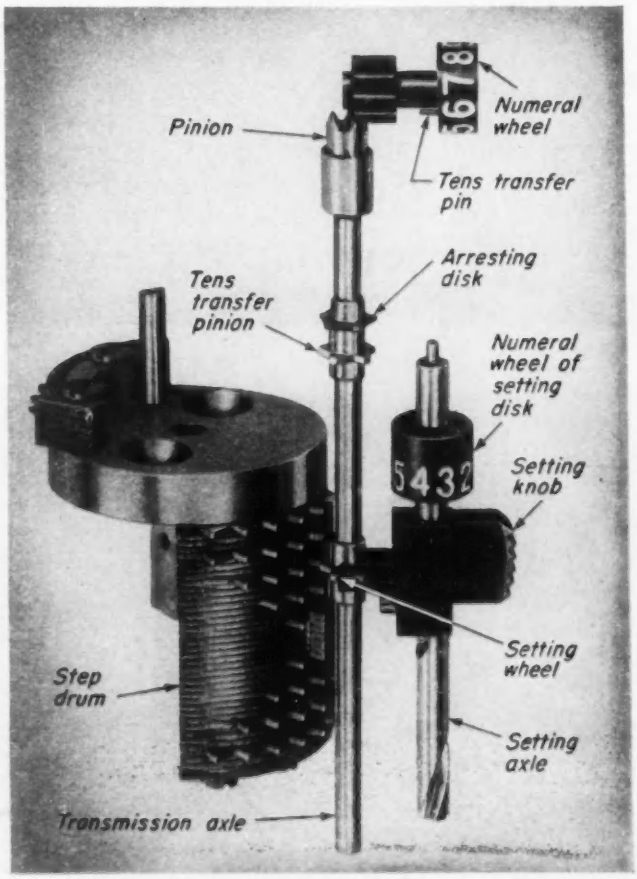
On its circumference the step drum has 19 rows of gear teeth, each row with a number of teeth ranging from one to ten. Nine rows are for addition, and nine rows carry the complementary digits of the addition rows, since subtraction is performed by adding complements. One row has ten teeth for first digit subtraction. When subtracting, all digits from two to eight are complemented to the false complement nine, but digit No. 1 must be complemented to the true complement ten. So the axle of digit No. 1 has an additional Cog wheel which is struck by the top row of ten teeth when subtracting.

Calculations are performed by driving the drum past each of the setting wheels to transfer a number corresponding to the number of teeth encountered. An automatic locking device prevents rotation in the wrong direction so that there is minimum wear of rotating parts. The calculator has been tested

TRANSMISSION OF NUMBERS. As setting knob is pulled down, it rotates the setting axle so that the proper number appears on the setting dial. At the same time it pulls down the setting wheel to a position on the toothed step drum where the number of teeth corresponds to the number set. Turning the operating handle revolves the main axle which rotates the drum so that it acts successively on each of the eight setting wheels. The rotation of each setting wheel is transmitted through the transmission axle to a pinion which drives the numeral wheel in the result dial. This cut shows one digit operation.

TEN'S TRANSFER MECHANISM. As the zero on the numeral wheel is moved so that it is visible in the result dial, the tens transfer pin in the wheel depresses the tens transfer slide of the next digit. The slide then depresses it's tens transfer pinion so that it contacts a single tooth in a plate above the step drum and on the same axle. This tooth moves the pinion one step forward adding one to the next digit. The pinion is then returned to its original position by a curved plate behind the tooth.

TOP VIEW of machine (insert) show six place counter dial, and 11 place result dial. Clearing lever is locked during operation by release button. When released, one complete turn clears both dials. But each dial can be cleared independently, by rotating the clearing lever overall the openings of that dial. Stops at the boundries between the counter and result dials assist independent clearing.



Performs Engineering Calculations

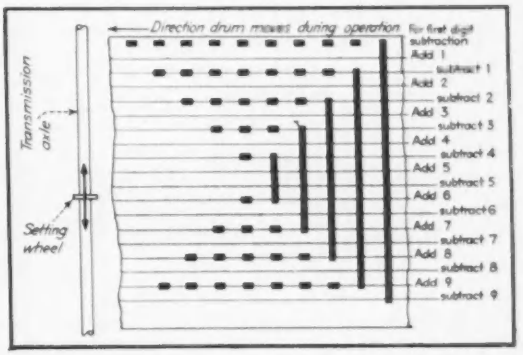
with 40,000,000 revolutions without appreciable wear.

Major components of the machine are: the carriage that can be moved to six different positions for multiplication and division; the number transmission mechanism; the ten's carry mechanism; and the result and counter dials.

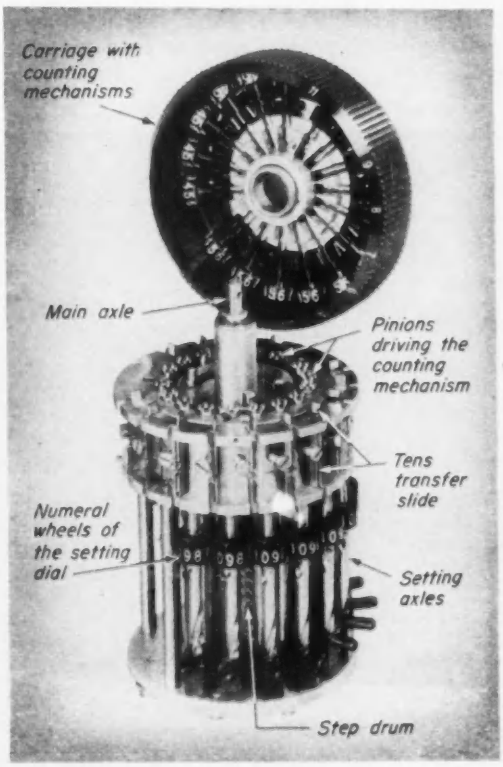
This precision calculator that weighs eight oz performs addition, subtraction, multiplication, division, squaring, cubing, and square root operations. The number set is transferred to the result dial once for each turn of the operating handle while the revolution counter records the number of these turns. Automatic devices prevent errors from mishandling. For instance, if one turn too many is made, it can be eliminated by a turn of the handle with the axis in the other position (subtracting instead of adding).

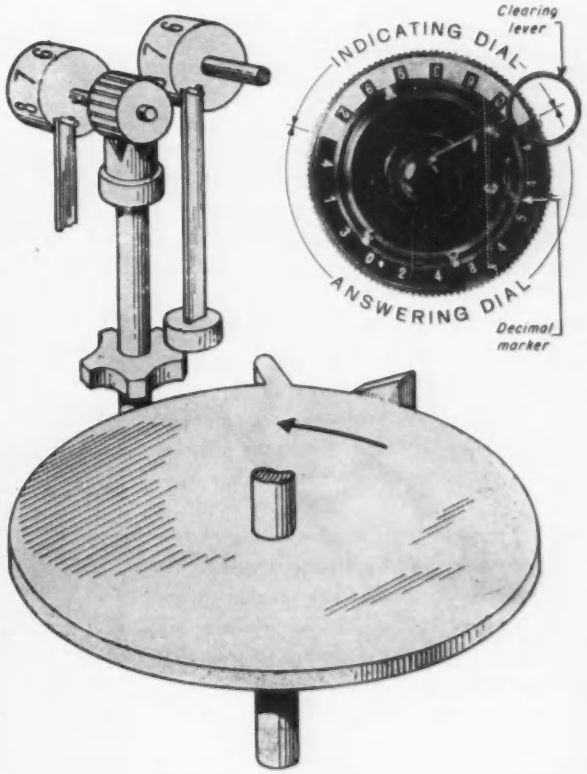
Capacity of the machine is 8x6x11 places. Eight place digits can be set for addition or subtraction; six place multipliers can be used; and maximum results of eleven places can be obtained.

In Canada, the Curta is distributed by the General Adding Machine Company, Toronto; and in the United States the distributor is the Curta Calculator Company, Chicago, Ill.



SCHEMATIC of toothed portion of step drum explains how addition and subtraction operations are performed. During normal operation, teeth on the addition lines mesh with the setting wheels, adding a number corresponding to the number of teeth encountered. For subtraction, the operating handle is extended, raising the drum so that subtraction lines engage the setting wheels; subtraction is performed by adding the complement of the number that is set. Here wheel is set to add 6.





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Mechanical Sensor for Automatic Check Signer

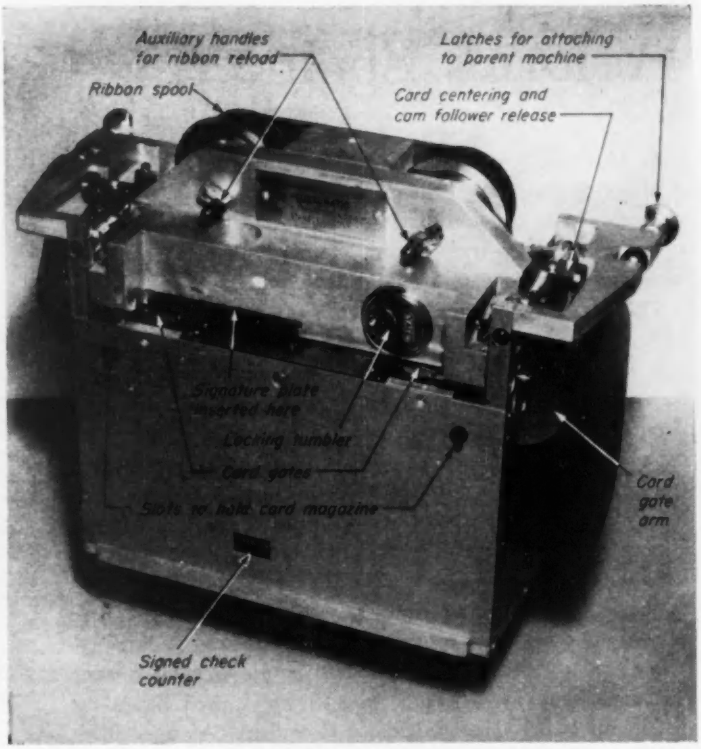
A mechanical sensing device with a finger-like sensing rod picks out checks for high-speed automatic signing in the Customatic Check Signer designed by G. H. Leonard, of the Stamford Tool and Die Corporation, Stamford, Conn. When this sensing rod locates a control hole in the proper place on the check, the mechanism releases a hammer that prints the signature at a specified position on the check. The signer was designed to fit on the back of a Remington-Rand Posting Interpreter and it receives cards and checks from the parent machine, straightens them, identifies them, signs only the checks, counts the number of checks signed, and then delivers them to a card magazine or receiver.

The sensor acts as a safeguard to prevent the signing of improper checks and identifies the checks from control cards that the parent machine uses to print information on the checks.

When the assembly is running, there are four possible sequences for the sensing mechanism. If the signer is locked into the inoperative position by the key and tumbler, an interlock fits into the sensor rod and holds it in a locked position that prevents the hammer from striking. In signing position with the proper signature plate in place, the key turns the machine to operative condition and a spring-loaded cam follower moves the sensor through three positions after the card is centered. The counter is tied to the printing hammer and counts only checks that have been signed.

Ribbon reversing mechanism uses a change in the geometry of the ribbon spool to reverse direction instead of the tension of the ribbon. For advancing, the spools are end loaded against friction disks by springs that can be swung aside to release the tension and allow manual rewinding.

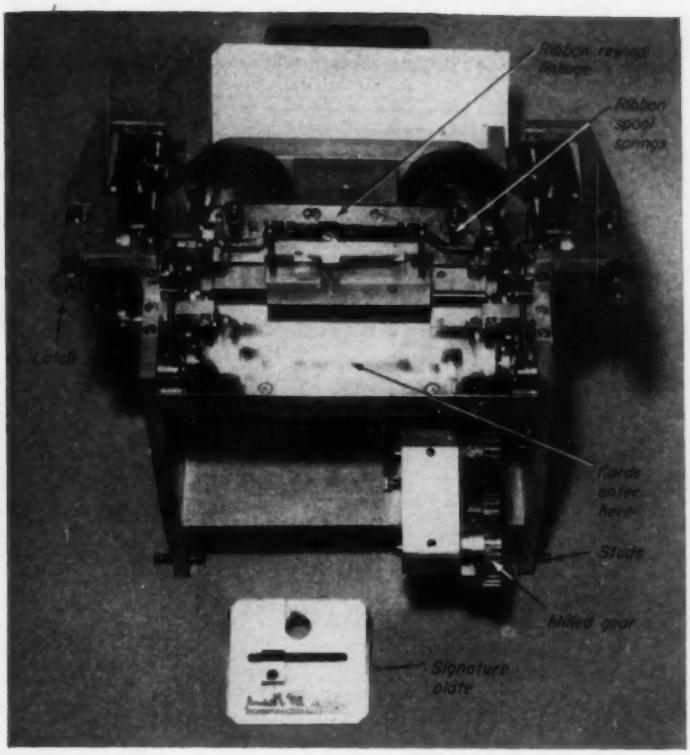
Milled gear, latches and studs permit attaching the signer to the parent machine without tools.



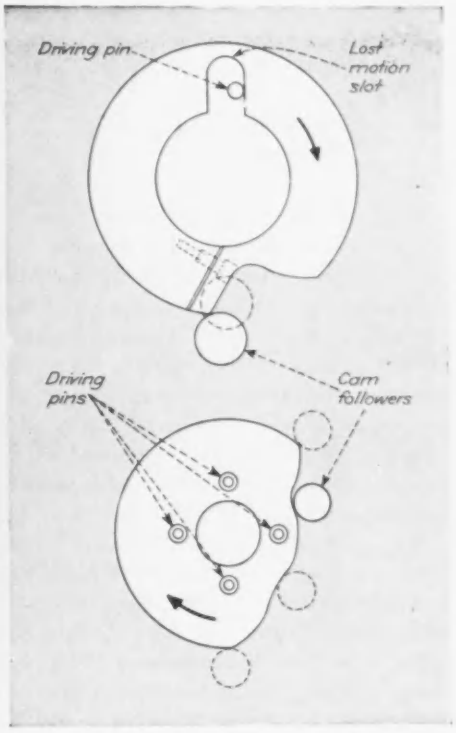
AUTOMATIC CHECK SIGNER machined from dural plates receives cards from parent machine, straightens cards, identifies checks, signs checks, counts checks and discharges them at rates up to 12,000 per hour. Locking mechanism makes unit operative or inoperative and prevents the insertion or removal of signature plates by unauthorized personnel. Key cannot be removed with unit in operative condition.

SENSOR AND PRINTING MECHANISM. CASE I. When not signing checks, key is turned to inoperative position and interlock maintains sensor in locked position. Locking pin in retracted position bears against locking screw A and prevents hammer from striking and printing. CASE II. When in signing condition, the signature plate is in position and key turns to operative position to retract interlock from sensor rod. Sensor tends to rise through 3 positions, lifted by a light spring. (A) Card with no control hole is not a check. Sensor tip raises card against signature plate, and the locking pin can rise no higher than position 1 where is still bears against locking screw A and keeps the hammer from tripping. No signature. (B) Card with proper control hole permits sensor tip to rise through hole into slot in signature plate until shoulder of sensor strikes the card. Locking pin rises to position 2 where it does not interfere with the hammer. When cam follower drops into recess in hammer cam, the hammer strikes, prints signature and actuates counter. (C) When no card is in place, sensor point rises into hole in signature plate and locking pin moves to position 3 where locking screw B prevents the hammer from tripping.

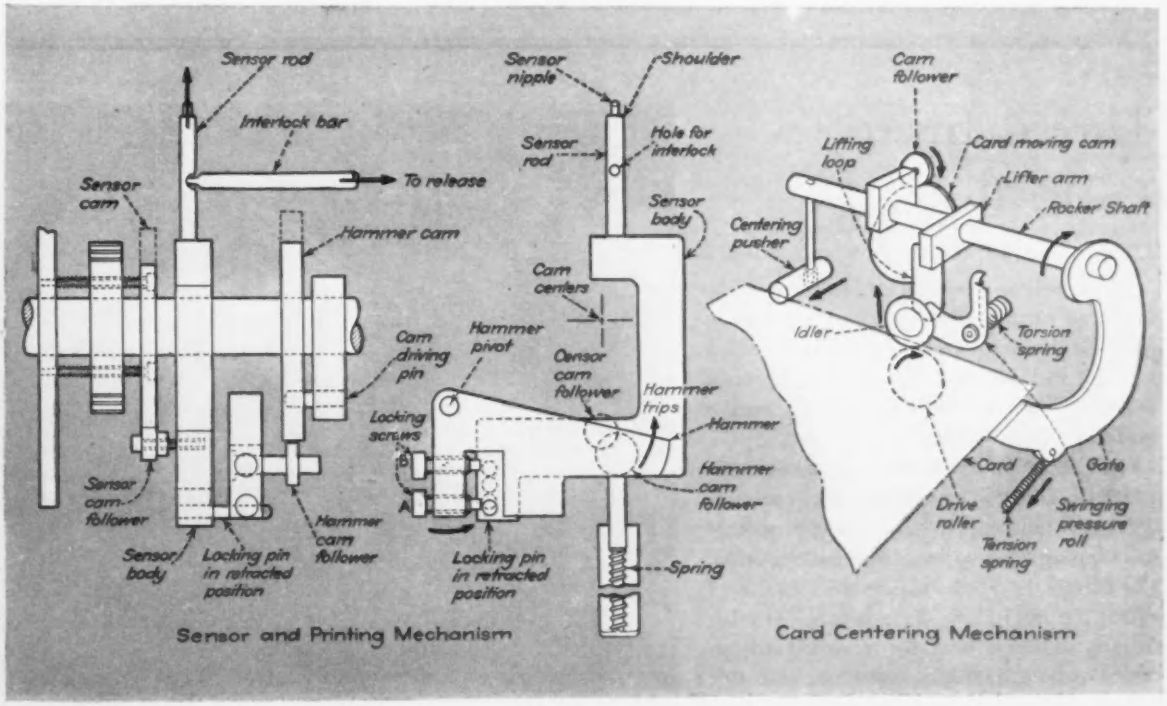
CARD CENTERING MECHANISM is located on each end of the signer. If card enters check signer askew, it moves until front edge hits a gate, and then pivots on that gate until both gates are contacted. Then device automatically straightens card. When straightening phase starts, card-moving-cam is high and centering pusher is retracted. As cam recedes, tension spring acting through the gate and rocker shaft force the cam follower onto the cam. The rocker shaft rotates lifting the idler wheels and moving the centering pusher to center card.



REAR VIEW shows attaching devices. Milled gear fits mating gear on parent machine in only one position and automatically puts signer in proper phase with parent. Latches fit parent machine only if gears are properly meshed. Studs fit slots on parent machine and permit swinging signer down when servicing the parent unit. Power to operate all functions is transmitted by the milled gear.



CAMS that phase the hammer (above) and sensor (below) are pin driven and mounted on ball bearings. Hammer trigger action is caused by spring loaded cam follower overdriving its cam. Lost motion slot affords room for driving pin when follower drops into recess.



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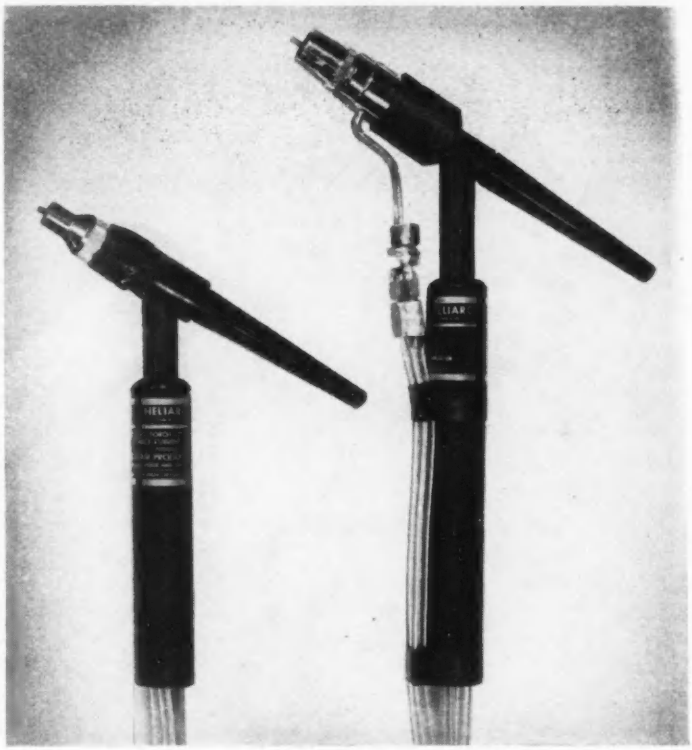
Redesign Boosts Torch's Capacity

Improved cooling as the result of locating the water jacket close to the arc instead of in the torch body permitted the Linde Air Products Company to increase the capacity of their Heliarc welding torches without increasing weight or size. When welding heavy aluminum or stainless steel sections with the old design, it was necessary to supply additional cooling water to the gas cup by external tubing that decreased the welder's visibility.

By using small diameter tubing in the torch body capable of withstanding molding pressures up to 15,000 psi, they were able to insulate the torch body with a plastic material that offered better resistance to softening and melting during heavy welding operation instead of plastic that could be molded at 200 psi to prevent crushing the water jacket and which softened and melted during high temperature service.

The torch is designed to use a metal nozzle for dc operation up to 300 amps and a ceramic nozzle for high frequency ac welding up to 250 amperes.

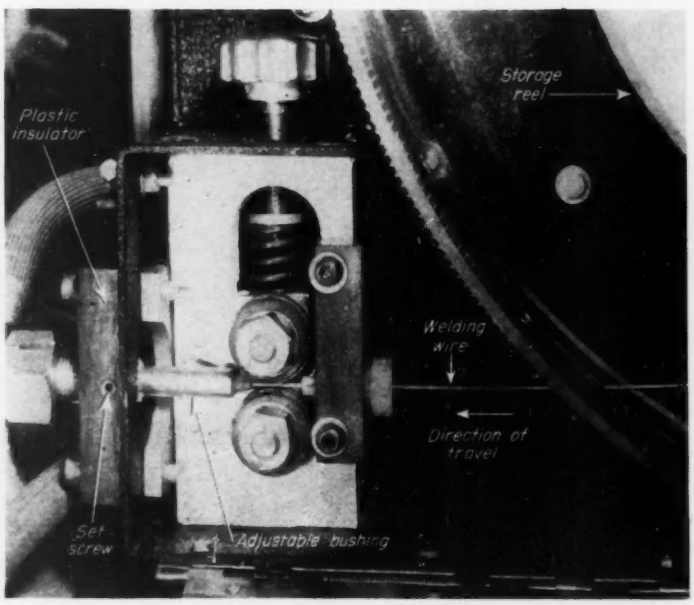


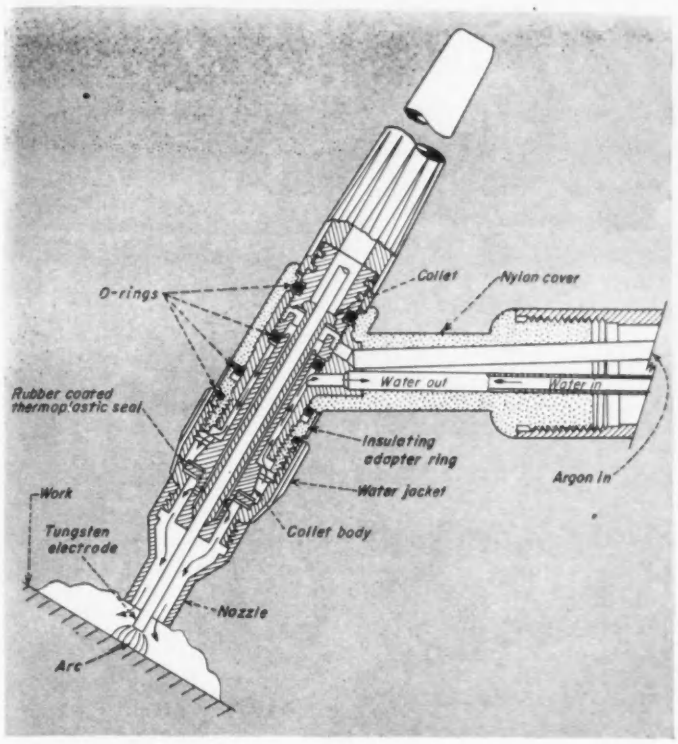
"HELIARC TORCHES:" new design (left) compared with old design (right). More efficient cooling system permits removal of external plumbing to increase welder's visibility, increase current capacity and reduce size of torch. Since the redesigned torch head is shorter than the old design, the tungsten electrode stub loss is reduced 50 percent and welder visibility is increased. Hose is connected to torch through nut and nipple connections. Ceramic nozzle prevents arcing from the torch before arc is struck when using high frequency ac.

Thread Insert Locks Bushing

Three helical wound wire inserts made by Heli-Coil Corp., Danbury, Conn. are used to lock the bushing assembly, through which welding rod passes to a laminated phenolic insulator block in the automatic arc welder made by the Air Reduction Co., Inc.

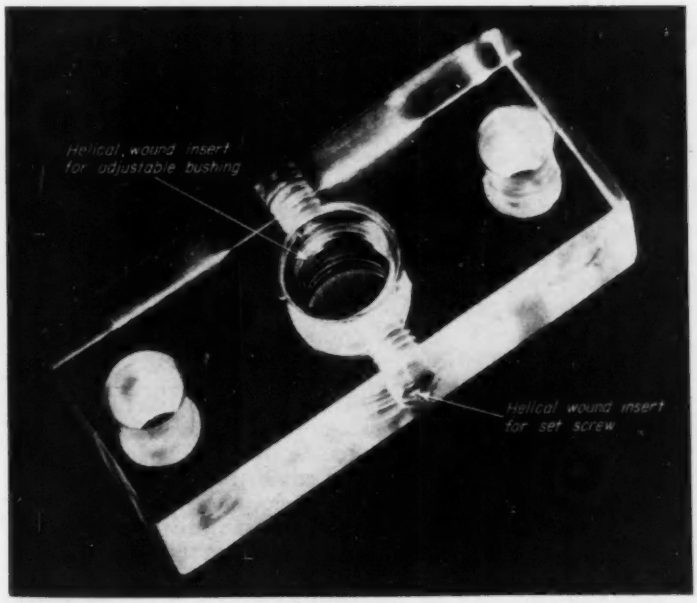
One large insert forms the threads on which the adjustable bushing turns; while the other two hold socket head screws that keep the adjusted bushing from changing position. The diamond shaped stainless steel wire from which the inserts are made provide metallic threads in the plastic for repeated adjustments without damaging the block.





FLOW OF FLUIDS. Argon enters through torch body, flows on outside of collet to prevent gas turbulence, and passes through collet body into nozzle. Water enters through torch body and passes down broached slot in collet body to the water jacket. Water leaves the jacket in broached slot on opposite side of collet body. Electric power enters through braided copper cable that also carries the cooling water away from the torch. Dirt or obstructing material can be removed by inserting wires in the flow passages to clean out the tubes.

NEW BODY DESIGN (left) is strengthened by using small diameter tubes instead of large diameter enclosed body water jacket (right). This reduces production rejects and permits increasing molding pressure from 200 psi to as high as 15,000 psi. In the new design water flows through the torch body to the head instead of to a water jacket in the body.



PLASTIC insulator block in automatic arc welder prevents welding current in continuous rod from grounding out through frame, and supports adjustable threaded bushing through which the rod passes as it travels from supply reel to the delivery gun. Bushing is adjusted to fit size of welding wire that is used.

TRANSPARENT plastic block shows how inserts are placed. The set screws contact the outside diameter of the bushing insert and cause sections of it to bind the threads of the bushing so that the insert distributes the locking forces over large area of the threads and prevents damage to the bushing.

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Current Trends in Potentiometers

PHILIP S. SCHMIDT
Stromberg-Carlson Company

Fig. 1

Clarostat Mfg. Co., Inc.

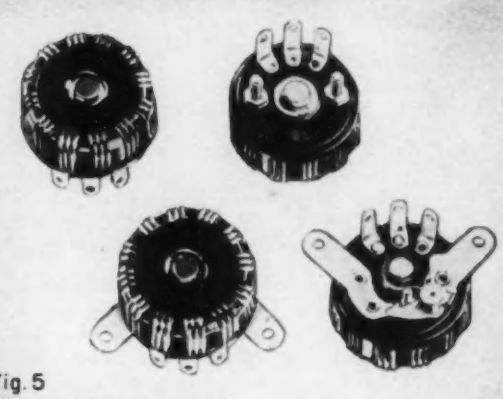

Fig. 5

Centralab Div. Globe-Union Corp.

Today's demands have expanded the groups of potentiometers available to the product engineer. Among the newcomers are: Miniaturized, high torque, precision-taper and helical units. Here are details on their construction and use.

DESIGNERS have of late become interested in the potentiometer as a machine component. The reason is simple—added flexibility is required for new control circuits. And potentiometers—electrical flow control valves—provide that flexibility.

Several physical arrangements are possible for potentiometers. In one design, the resistance element lies along a straight line or in a flat plane with the contact arranged to pass linearly along it. More common is the construction involving a circular resistance element. Potentimeters of this type have a centrally-located rotatable shaft which carries a contact-making arm. Alternatively, the shaft may be fixed and the resistance element rotated around it. Slip rings are usually necessary in the latter arrangement.

Potentiometers may be conveniently grouped for review according to their most outstanding characteristic. Assigning arbitrary group numbers:

Group I—Low cost potentiometers.

Group II—Power handling potentiometers.

Group III—High precision potentiometers.

Those of Group I are made in large numbers for consumer goods, such as television receivers and radio sets. Group II potentiometers are usually referred to as "power type" components and are used as field rheostats and other relatively heavy-current applications. Group III units, called "precision potentiometers", find application as position-information transmitters, as mechanical modulators, and as elements of computer devices. Each of these groups, of course, contains models of additional special characteristics, such as small size and especially high or low torque specifications.

Group I Potentiometers

The low cost group may be subdivided according to the type of resistance element and in order of increasing cost, as follows:

1. Carbon
2. Composition
3. Wire-wound

This also happens to be the order of increasing stability and accuracy.

Some carbon potentiometers are of

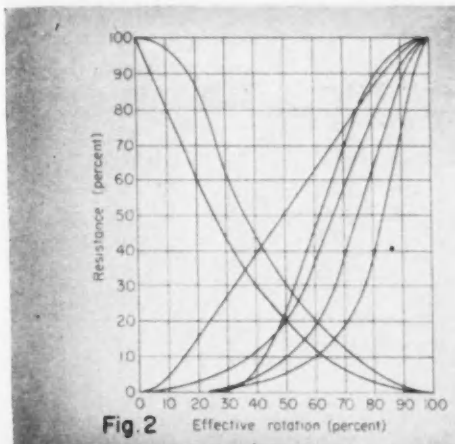

Fig. 2

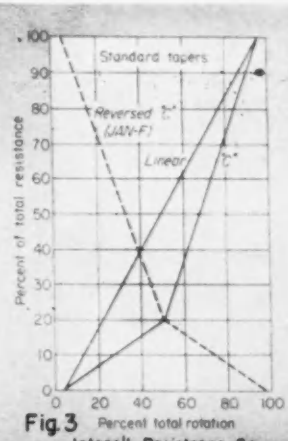

Fig. 3

Intern'l Resistance Co.

Fig. 4

Clarostat Mfg. Co., Inc.

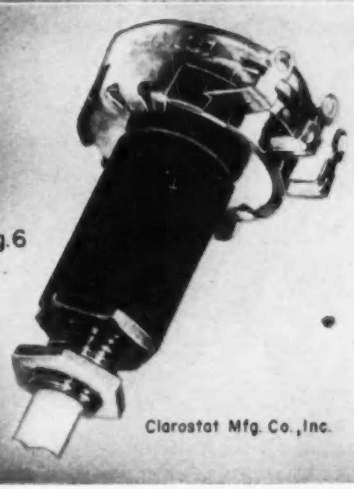

Fig. 6

Clarostat Mfg. Co., Inc.

Table I—Characteristics of Low-Cost Potentiometers

Type	Resistance (ohms)	Power (watts)	Frequency Performance	Tapers Available
Deposited Carbon	500 ohms to 10 megohms	0.5 - 2	Relatively good; limited by distributed capacity	Many; see Fig. 2.
Composition	100 ohms to 10 megohms	0.25 - 2	Same as deposited carbon	Same as deposited carbon.
Wire-Wound	0.5 ohm to 100,000 ohms	1 - 10	Poor, limited by high inductance	Linear, or simple combination of linear

Fig. 1—Resistance elements for low cost composition-type potentiometers. These are formed by molding a resistance compound on an insulating base. Fig. 2—Curves showing the variation of resistance with shaft rotation for assorted deposited carbon and composition potentiometers. Each taper curve is selected for a definite purpose. Fig. 3—Resistance tapers for a wire-wound potentiometer. Variation in taper such as that of curve C is accomplished by changing wire size at some point of the winding. Fig. 4—Potentiometers are usually mounted on chassis or panel by means of integral threaded bushing. Stamped metal housing offers mechanical protection only. Fig. 5—Group of subminiature carbon potentiometers, each about the size of a dime. Housing serves also as control knob. Fig. 6—Unit with insulating bushing for electrically isolating potentiometer body from chassis. This construction is required for high voltage applications in both control and communications equipment.

the deposited type, in which the resistance material is applied to an insulating base material by painting, spraying or a similar process. Base materials are usually from the phenolic group. Also in the carbon group are composition potentiometers, made by heat- and pressure-molding a resistance compound onto a base member. Both deposited carbon and composition types employ resistance elements of flat, circular configuration, such as shown in Fig. 1.

Low-cost wire-wound potentiometers are made by winding resistance wire on a suitable form. This form can be a rectangular card that is bent into a circular shape after winding is completed. The movable arm contacts the winding either on the width or the thickness dimension. In some instances, the resistance wire is wound on a long, thin wire or rod form which is formed into the required circular shape after winding is complete. The form must be insulated. This type of winding is known as the violin-string or Kohlsrausch construction.

Electrical characteristics obtainable in conventional low-cost units are contrasted in Table I. Note that choice is restricted in certain ranges. For example, the choice above 100,000 ohms is only between deposited carbon and composition, while dissipation over two watts dictates the use of a wire-wound construction. Although no potentiometers offer particularly good high-frequency performance, the table indicates that the wire-wound is poorer than the composition and deposited carbon types. A fact not evident from the table is the availability (usually on special order) of deposited carbon and composition types with one or two fixed taps at various locations on the resistance element.

The manner in which the resistance between the tap or slider terminal and one end terminal varies as a function of tap position is known as the taper of a potentiometer. Many tapers are possible with deposited carbon and composition potentiometers. Some standard taper curves are shown in Fig. 2 to illustrate the characteristics that can be obtained.

Wire-wound tapers present special problems, since any departure from a linear relationship involves changing

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wire size at some point in the winding process. One such change is the limit in most commercial lines of potentiometers. In Fig. 3 are reproduced sample curves obtainable for a two watt unit. Aside from resistance variation due to taper, there is the problem of obtaining the exact total resistance desired in the resistance element itself. Tolerances on commercial low-cost potentiometers run as high as ± 30 percent, particularly above 100,000 ohms.

The majority of low-cost potentiometers are arranged for single-hole mounting in a a panel or chassis. The mounting comprises a threaded bushing (⅜-32 NEF-2) passing through the body of the potentiometer housing (Fig. 4). The bushing serves as a mounting and a shaft bearing.

Also visible in Fig. 4 is the stamped metal housing generally furnished on low-cost potentiometers. This is secured to the insulating base by ears or tabs. While this type of housing affords little protection against moisture, fungus, and similar environmental effects, the requirements of consumer goods applications are satisfied and cost is kept reasonably low.

Deposited carbon and composition potentiometers may measure as much as 1¼ in. in diameter and ⅝ in. deep in the circular body portion. With the postwar trend toward miniaturization, however, two 2-watt potentiometers measuring only 1⅛ in. diameter by ½ in. thick have become available. In addition; miniature types have been developed. One model capable of handling ½ watt is only ⅝ in. diameter by 7/16 in. deep. A miniature dime-size unit is shown in Fig. 5. The protective housing serves as the actuating knob. Now a common component of hearing aids, it is finding application in miniaturized military equipment.

The resistance element of potentiometers is frequently held in place by clamps at the ends. This is particularly true of wire-wound potentiometers, where the resistance wire, being non-solderable, can be contacted only by crimping a contact clip over the ends of the wound form. The contact arm rides up on the clip after it reaches the end of travel on the resistance element. When on the clip, however, movement of the arm does not vary the resistance. Consequently, the angular travel of the contact arm is less from an electrical standpoint than from a mechanical standpoint. In the case of composition potentiometers, for example, the total mechanical travel may be between 260 and 300 deg, while the corresponding effective electrical rotation amount to a total of only 240 to 280 degrees.

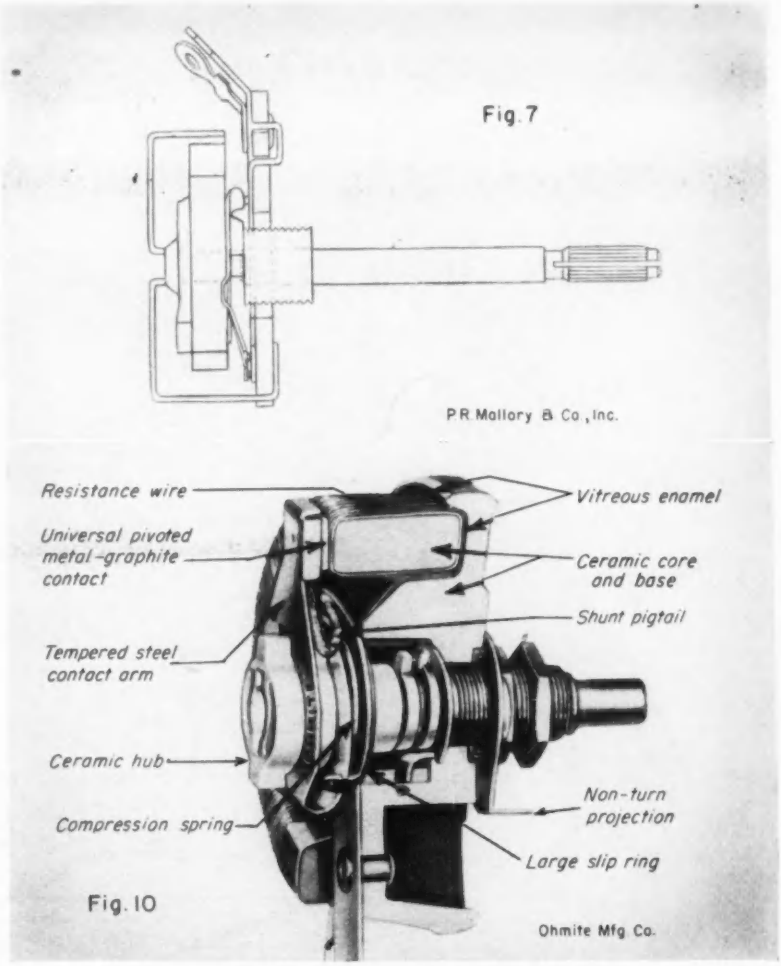


Fig. 7—In this new design, potentiometer body is indented to support second bearing for operating shaft. Conventional units use one bearing so shaft is more liable to misalignment. Fig. 8—Multiple-section potentiometer comprises three units mounted on a single shaft. Any number of units can be ganged and on-off switches added.

Voltage breakdown is sometimes of importance, as in selecting focus and brilliance controls for cathode-ray tubes. Since rated breakdown voltage is usually about 1,000 v for radio-television types and 500 v for military applications, it is the practice to insulate the potentiometer bushing and shaft from the chassis of the apparatus. For uses of this sort, insulating couplings such as the one shown in Fig. 6 are available, or shafts made of insulating material such as nylon may be obtained.

A recent development in low-cost potentiometers is the model diagrammed in Fig. 7. The rear cover is indented to provide a bearing surface.

The increasing use of electronic gear under severe vibration conditions has led to the introduction of high-torque potentiometers. Although more force on the shaft is required to set one of these models, vibration is unlikely to alter the setting accidentally. Some of the smallest potentiometers are now available in high-torque versions.

Multiple-section models of low-cost potentiometers are readily available. Some of these can be assembled in the field. In multiple-section potentiometers, two or three units are ganged in tandem for actuation from a common shaft. A triple potentiometer, with a-c switch attached, is shown in Fig. 8. A recent trend has been toward the design of interchangeable composition and wire-wound units for ganging, thus affording the widest possible variety of multiple controls. Also, a number of miniature potentiometer lines are now available in dual and even triple versions. The dual wire-wound trimmer model shown in Fig. 9 is capable of dissipating three watts per section, yet measures only ⅞ in. in diameter by ⅜ in. in depth.

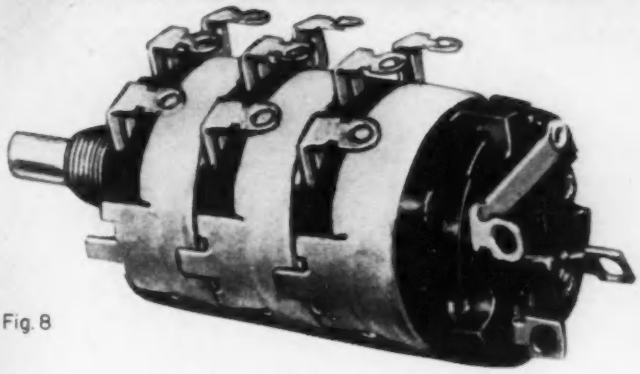
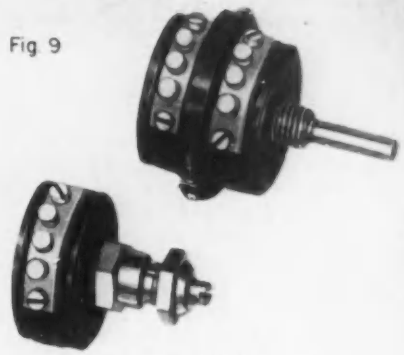


Fig. 8

Clarostat Mfg. Co., Inc.

Fig. 9



Waters Mfg. Co.

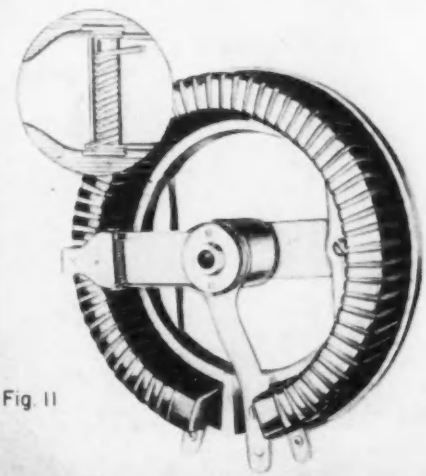


Fig. 11

P.R. Mallory & Co., Inc.

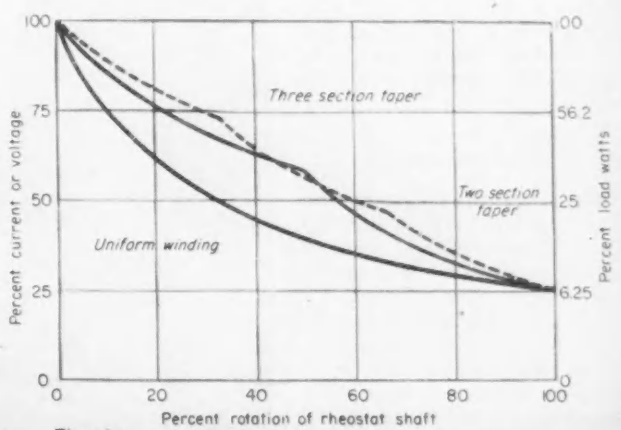


Fig. 12

Ohmite Mfg. Co.

Fig. 9—Dual wire-wound potentiometer dissipates three watts per section. Yet each unit measures only ¾ in. diameter by ¾ in. deep. Fig. 10—Construction of wire-wound, power-type rheostat. Note slip ring for current transfer, and overtravel stop.

Fig. 11—Brush is a prime wear point in power potentiometers. Hinged brush arm (above) makes for easy brush replacement. Fig. 12—Curves showing the contrast between tapered and uniform winding. Section tapers are achieved by varying wire size.

Group II Potentiometers

Where powers from 25 to 1,000 watts must be dissipated, the use of a "power-type" potentiometer is indicated. Though carbon pile models are available, the wire-wound type is more commonly specified.

The construction of a wire-wound power potentiometer is shown in Fig. 10. A flat ribbon of resistance wire is wound on a circular ceramic core of rectangular cross-section. The ends of the winding are secured in place by clamps that have integrally-formed lugs for making connections. This assembly is cemented to a ceramic base plate with vitreous enamel, which also coats most of the exterior surface of the wound core to protect and insulate the wire.

Still another construction for power type potentiometers is enclosed in a double-walled ceramic case. This serves as a foundation unit to receive the resistance element, which comprises resistance wire wound on an insulated metal core. A cold-setting inorganic cement secures the winding in place. The contact-making brush is of graphited-copper, mounted in a cradle-type arm. This brush, or shoe, contacts both the winding and a collar ring and provides a short conduction path.

The brush is one of the important portions of power-type potentiometers, as proper brush design is a factor in preventing wear. In addition to the types already illustrated, the hinged-arm type shown in Fig. 11 is available. This type has the advantage of allowing easy replacement of the brush without danger of altering its pressure on the winding.

Power-type resistors are made in resistance values as low as 0.5 ohms and as high as 10,000 ohms. Physically, resistors of the power class range from 1 9/16 in. diameter for the 25-watt size to about 12 in. in diameter for the 1,000-watt size.

Tapered windings are available in power-type potentiometers, just as in the low-cost classification. Tapered windings are produced by varying the spacing between turns of a given wire size or by using as many as five sizes of wire for various portions of the winding. The availability of power-type rheostats using more sections of different wire size than those in the low-cost classification was brought about by the demand for motor control rheostats producing a linear relationship between motor speed and knob position. Tapered windings are also used where a high current must be passed at low resistance settings. In Fig. 12, some of the curves obtainable in tapered power-type resistors are

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contrasted with that of a uniformly wound unit.

Power-type potentiometers are supplied with many of the features available in low-cost potentiometers. They may be ganged with the aid of special brackets. Coaxial-knob controls employing concentrically-mounted units of different sizes may also be had. This construction is useful where panel space must be conserved or where the smaller control is to act as a vernier for the larger. External-circuit switches may also be operated by power-type rheostats. For example, a toggle switch may be actuated at the end of travel by an arm rotated by the contact-arm shaft of the potentiometer. An additional tap for switching purposes may be included on the winding core. Optionally, the tap may be omitted to provide a dial-off position. Many shaft variations, such as screwdriver-slotted shafts, may also be obtained in potentiometers of the power type.

Group III Potentiometers

Potentiometers belonging to this group possess high accuracy and stability. Most applications of precision potentiometers involve the measurement of some quantity—either of the position of a movable object in a mechanism, or, by physical analogy, of some factor in a computation.

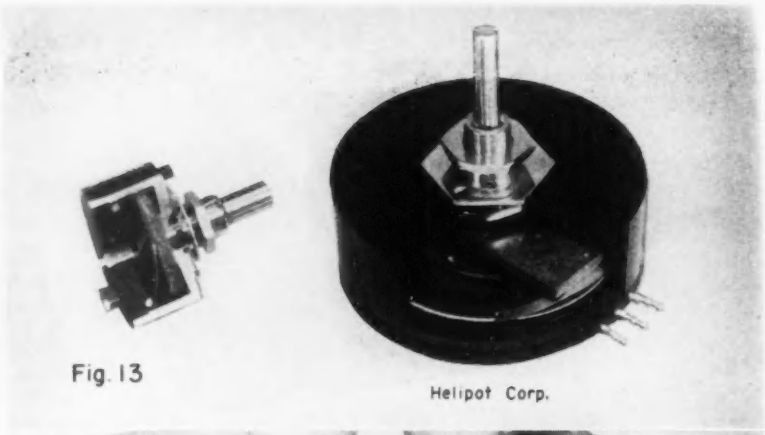
Because of the nature of these applications, accuracy is of paramount importance. Accuracy is achieved by careful design, precision machining and the use of the most suitable materials for each purpose. One manufacturer holds the diameter of shafts and pilot bushings to a tolerance of ± 0.0000, -0.0005 inch. Though plastic materials like Bakelite are used in some cases, housings are frequently machined from aluminum. Shafts are made of stainless steel and dimensioned on centerless grinders. Powdered bronze and even ball bearings are used, and great care is taken to insure that the shaft is concentric with the resistance element.

Precision potentiometers are almost universally of the wire-wound type and of either single-turn or multi-turn helical units. To the first class belong the large-diameter units of the sort illustrated in Fig. 13. These are about five inches in diameter and are available in resistances from 10 ohms to 300,000 ohms, with a five-watt rating. Smaller units usually permit ganging. In some cases as many as 20 units may be driven in tandem by a single shaft. Newer designs allow linear units to be ganged with non-linear ones.

One shortcoming of the single-turn type of precision potentiometer is the large diameter required to accommodate a wire of reasonable length and therefore of adequate resolution. This has led to the development of a new type of potentiometer having a number of turns arranged in a helix, which is coaxial with the shaft of the potentiometer. The wire is usually disposed like a spiral spring inside an insulated housing and the contact arm is arranged to follow the resistance element in the same manner as a streetcar trolley follows an overhead cable.

Helical potentiometers may be had with resistance values ranging from 10 ohms to 1 megohm, a resistance tolerance of $\pm$ five percent and a linearity tolerance of ± 0.05 percent. Models are available having three to 40 turns on the helix with corresponding winding lengths from $13\frac{1}{2}$ to 373 in. Another manufacturer uses a winding length of 43.5 in. for all models and secures variations in resistance value by proper choice of wire size and alloy.

A recent trend in helically-wound potentiometers is the miniaturization of the earlier forms of these units. The model shown in Fig. 14 has a body measuring only $\frac{3}{4}$ in. diameter and $1\frac{3}{8}$ in. long, but it affords a resolution of about 0.015 percent in the 50,000 ohm size, and will withstand 1,000 v to ground. A bearing is provided at each end of the shaft, and the unit is completely sealed against dust. A unit of one in. diameter by one in. deep made by another manufacturer is rated at $1\frac{1}{2}$ watts in resistance values from 100 to 50,000 ohms. One of the largest helical potentiometers made is a 20-watt model which measures $3\frac{1}{2}$ in. by 6 in. deep. Helical potentiometers require special dials,



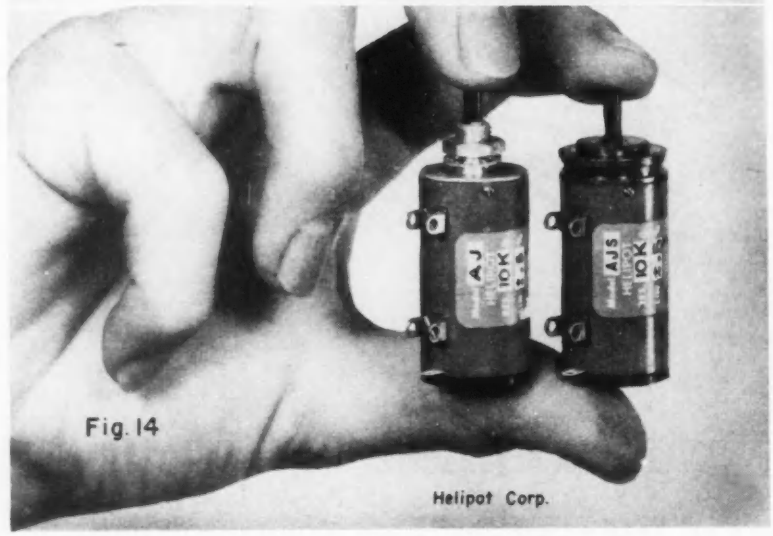


Fig. 13—Single turn precision potentiometers. Brush passes over looped resistance wire, which is concentric with shaft. Fig. 14—Miniaturized helically-wound potentiometer measures only $\frac{3}{4}$ x $1\frac{3}{8}$ in. Contact arm moves along helical spiral of wire. Fig. 15—Special dial is required for helically wound units. Above shows both angular position and turn location of the contact arm.

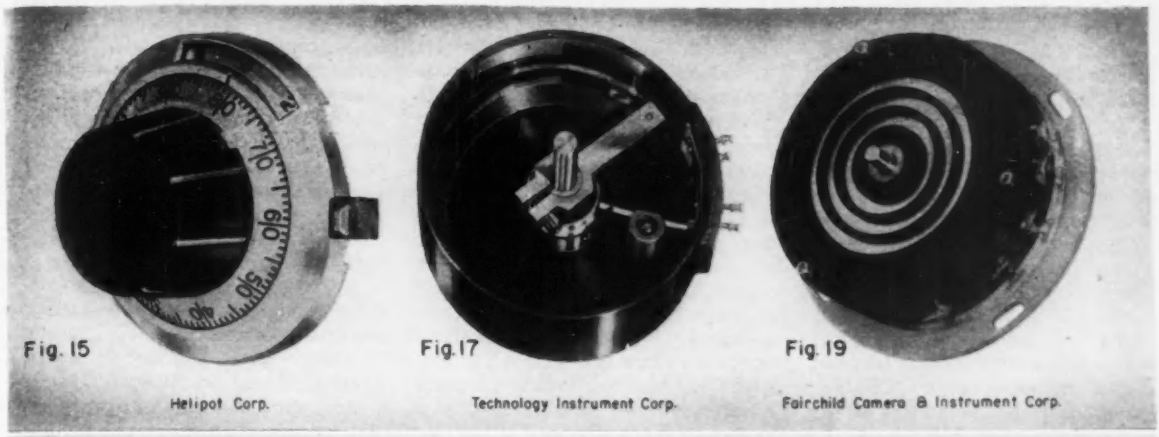


Fig. 15 — Helipot Corp.

Fig. 17 — Technology Instrument Corp.

Fig. 19 — Fairchild Camera & Instrument Corp.

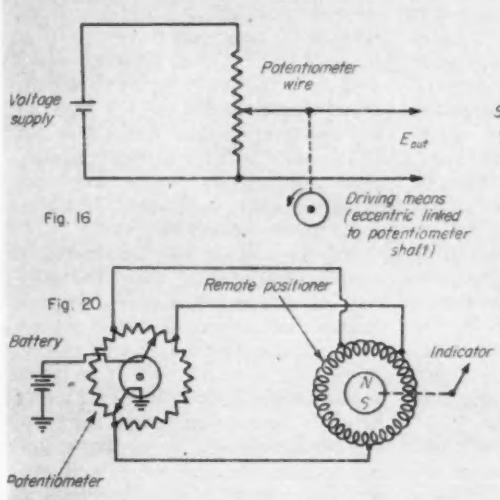


Fig. 16

Fig. 20

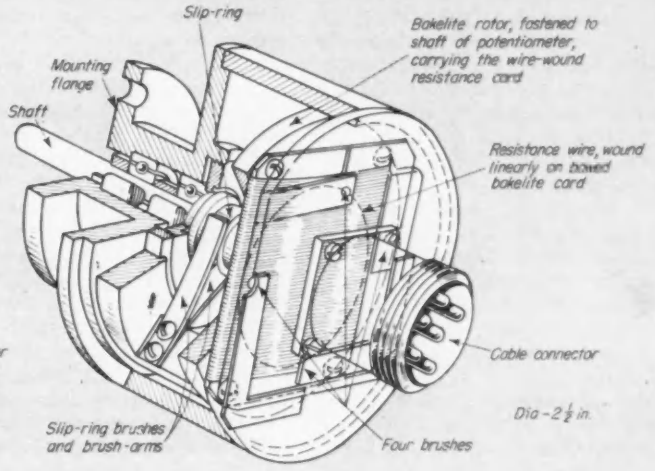

Slip-ring
Bakelite rotor, fastened to shaft of potentiometer, carrying the wire-wound resistance card
Mounting flange
Shaft
Resistance wire, wound linearly on boxed bakelite card
Cable connector
Dia - 2 ½ in.
Slip-ring brushes and brush-arms
Four brushes

Fig. 18

Fig. 16—A-c or d-c voltages can be changed or modulated to any desired wave form by means of a potentiometer. Wire is actually arranged in a circle. Fig. 17—Resistance wire of this unit is arranged to produce a logarithmic wave form. Hyperbolic, trigonometric and square-root functions are also obtainable.

Fig. 18—Card-type potentiometer is widely used in computer servos. Resistance wire is mounted on card or form that rotates with shaft. Fig. 19—In differential-type unit, both shaft and body can be rotated independently. Fig. 20—Use of potentiometer as the pick-up element in a remote positioning servo.

Fig. 15, because it is necessary to locate the contact arm not only as to angular position but also as to which turn it is resting on at a given time.

Applications

Precision potentiometers are frequently used as mechanical amplitude modulators. One circuit for such an application is shown in Fig. 16. The shaft is driven by a motor, either continuously or with a reciprocating motion. In the former case, the contact arm must be arranged for continuous rotation through 360 deg, in which case the winding may likewise be continuous or may have an interruption of only a few degrees in the neighborhood of 360 deg. The waveform of the voltage obtained between the tap of the potentiometer and ground thus depends on the resistance taper of the potentiometer winding.

Mechanical modulators usually employ potentiometers having a non-linear taper. Readily available tapers include those which produce logarithmic, hyperbolic, square-root and trigonometric functions. The potentiometer shown in Fig. 17, for example, has a winding form shaped to produce a 50 db logarithmic function with a resistance of 15,000 ohms ± five percent, using an external defining resistance of 47.4 ohms in series. This particular model has stops to limit the effective electrical rotation to 320 deg and is therefore used where driving motion is of a reciprocating nature. As shown in the illustration, this taper is produced by winding the resistance wire on a shaped winding card or mandrel. The slope of characteristics obtained by this method is limited by the tendency of the wire to slip when the winding form has too sharp a slope. Taper slopes are ordinarily limited to ratios of 200 to 1 and up to slopes as high as 1,000 to one.

External loading of a linear potentiometer adversely affects its linearity. This is an advantage, however, where non-linearity is desired. Potentiometers are available having as many as 60 adjustable taps to which shunting resistances may be connected to produce almost any desired taper. One model, for example, is available in resistance values from 10 ohms to 200,000 ohms, has an accuracy of ±0.025 percent and may be made to conform within ±0.01 to ±0.025 percent of a desired curve.

The non-linear potentiometer shown in Fig. 18 is of interest because it furnishes both sine and cosine output

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and has an unusual configuration. The resistance wire is wound on a square plastic card, arranged to be rotated by the shaft. Slip rings and brushes are provided for connection to the ends of the winding. Four fixed brushes spaced 90 deg apart trace a circular path on the card. If a fixed voltage is now applied across the winding, the voltage picked up by one of the brushes varies as the sine function, because the path necessary to produce this function is circular. The next adjacent brush, since it is 90 deg displaced, produces the cosine function.

Other trigonometric functions may be obtained in potentiometers of this type by varying the path traveled by the brush relative to the winding. It is, of course, possible to rotate the brushes and keep the card stationary.

The use of potentiometers in analog computers has led to the development of the type shown in Fig. 19. This employs a linear winding and both the resistance element and the shaft are independently rotatable through 360 deg. Connection is made to the resistance element through slip rings molded on the body. With this arrangement, the output voltage is proportional to the sum or difference of the angular movements of both body and shaft. This type, known as a differential computing potentiometer, is available in values up to 150,000 ohms, and is rated at five watts.

In addition to their use as elements of computers, precision potentiometers are also used as position transmitters. The mechanical amplitude modulator may be considered a use of this sort. In the main, however, position transmission is usually thought of as the conveying of information to a remote point where the position involved is changed at irregular times.

The d-c Selsyn system diagrammed in Fig. 20 is an example of reporter-type positioning. The transmitting potentiometer has a continuous 360 deg ring, or toroidal, winding tapped at 120 deg intervals, and is fed from a battery by two brushes insulated from each other and located 180 deg apart. The receiving indicator is based on Gramme ring principles, with a continuous coil also tapped at 120 deg intervals, the taps being connected to corresponding points on the potentiometer. A cylindrical permanent magnet forms the rotor of the receiver. The results obtained are comparable to those achieved with synchro transmitters and are available at lower cost.

Tiny potentiometers have been developed with operating torques as low as 0.003 in.-oz. This low torque, which is achieved by precision fitting and the use of jewel bearings, permits such potentiometers to be mounted on the glass bezel of dial indicating instruments. The shaft of the potentiometer, Fig. 21, is mechanically linked to the needle of the instrument, thus forming a position transmitter.

Potentiometers compete as information transmitters with variable transformers (selsyns), variable capacitors and photoelectric devices.

A circuit employing a potentiometer as a command transmitter is diagrammed in Fig. 22. A transmitting potentiometer and receiving potentiometer are connected in a bridge circuit, with a differential relay connected to the movable taps and a source of d-c connected on the other diagonal of the bridge. The receiving potentiometer is mechanically coupled to the shaft of the motor whose position is to be controlled and the contacts of the differential relay are connected to control the motor direction. The differential relay is of the type having a center-off position. In operation, the bridge is unbalanced when the transmitting potentiometer is placed in a desired position. The differential relay then closes and drives the positioning motor in a direction which will cause the receiving potentiometer to rebalance the bridge. When this condition is reached, the differential relay moves to its center-off position, thus stopping the motor until the bridge is again unbalanced by movement of the transmitting unit.

In some cases it may be desired to transmit information about the position of a member capable only of straight line motion. To avoid the use of a rack and pinion or similar motion converting apparatus, the translatory potentiometer shown in Fig. 23 may be used. Such potentiometers are usually supplied with linear characteristics and are therefore useful in studying high-amplitude displacements and low frequency motion or vibration.

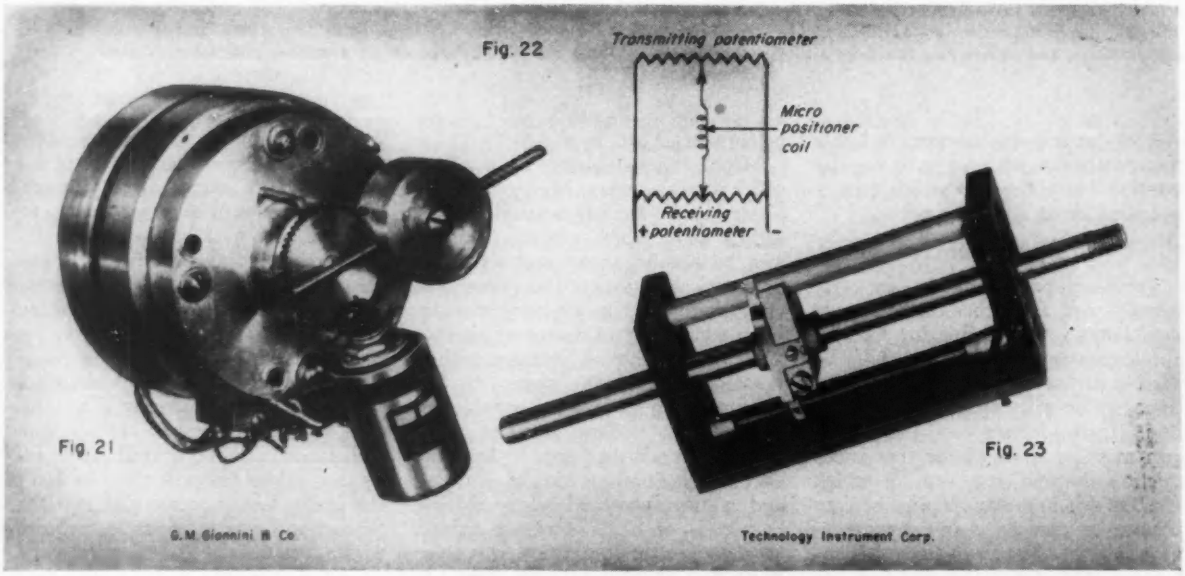

Fig. 21—Tiny potentiometer mounted at rear of an indicating instrument such as an altimeter. Potentiometer transmits reading to remote indicator, computer or recorder. Fig. 22—Bridge circuit is commonly used in potentiometer information transmitting systems. Positioning motor acts to keep bridge balanced. Fig. 23—Translatory potentiometer is arranged for straight line rather than rotary movement of the contact arm over the resistance wire. Such units are usually designed with linear characteristics.

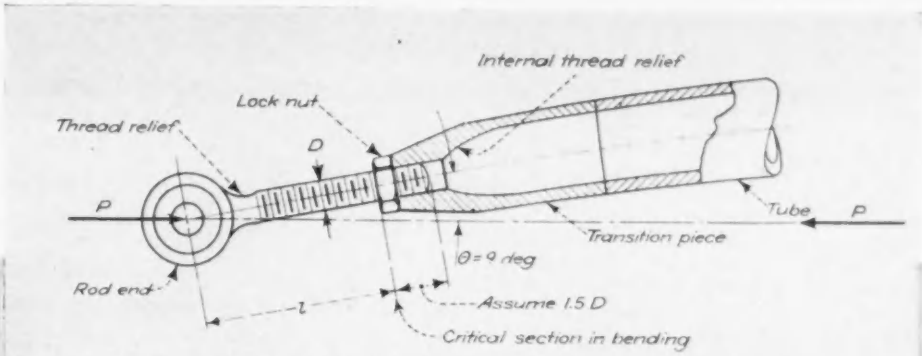

Fig. 1—Rod end with anti-friction bearing. Load is assumed to be applied at a 9 deg rotation of the rod end when checking critical section in bending.

Structural Analysis Of Control Rods

Design procedure for determining the adequacy of the structural strength of control rod ends in low speed and intermittent service applications. Strength of rod end shanks with anti-friction bearings and with spherical bearings. Column allowables for control rods. Beam column analysis for control rod ends.

F. M. HOBLIT
Structures Engineer, Lockheed Aircraft Corporation

ALTHOUGH CONTROL RODS are composed of simple structural elements, the occurrence of failures in service indicates that certain precautions should be taken in their analysis. Since most of the failures have occurred in the rod ends, this discussion deals chiefly with providing adequate strength of the rod ends. The methods given herein are in some instances rather arbitrary, but avoid undue labor in analysis and lead to satisfactory design.

For rod ends with anti-friction bearings, the manufacturer's static non-Brinell rating is both the static load that the bearing can withstand without damage to its serviceability as a bearing and the load under which the anti-friction bearing will operate satisfactorily at the low speed and intermittent service encountered in rod-end applications. For the capacity of an anti-friction bearing to be adequate, therefore, the only requirement is that the static non-Brinell rating not be exceeded by the design yield load, which is the load obtained by multiplying the limit load by the yield factor of safety.

For spherical bearings, manufacturer's ratings should be used only as an indication of static strength. To assure serviceability under conditions of relative motion, the bearing pressure (based upon the nominal bearing area given by sphere diameter times width of race) should be checked and should not exceed 10,000 psi at an applied load obtained as the product of the maximum load that can occur during relative motion and the yield factor of safety. The only bearing factor that should be applied in using this criterion is a factor of 1.25 when the bearing is subject to shock or vibration during motion.

The load that a spherical bearing will carry statically without damage to the bearing can ordinarily be assumed to be equal to or greater than the manufacturer's rating if such rating is given on a "limit-load" basis, or $\frac{2}{3}$ the manufacturer's rating if given on an ultimate basis. Such load must not be exceeded by the design yield load (limit load multiplied by the yield factor of safety).

Strength of Rod End Shanks

WITH ANTI-FRICTION BEARINGS. Because of manufacturing tolerances, eccentricities can always exist in control rod assemblies, and bending moments therefore are present. The critical section in bending in the rod end should be checked at ultimate applied load by assuming a 9 deg rotation of the rod end as shown in Fig. 1. The 9 deg angle is assumed to be the result of a $1\frac{1}{2}$ deg of tolerance build-up, which is caused chiefly by angularity in machining

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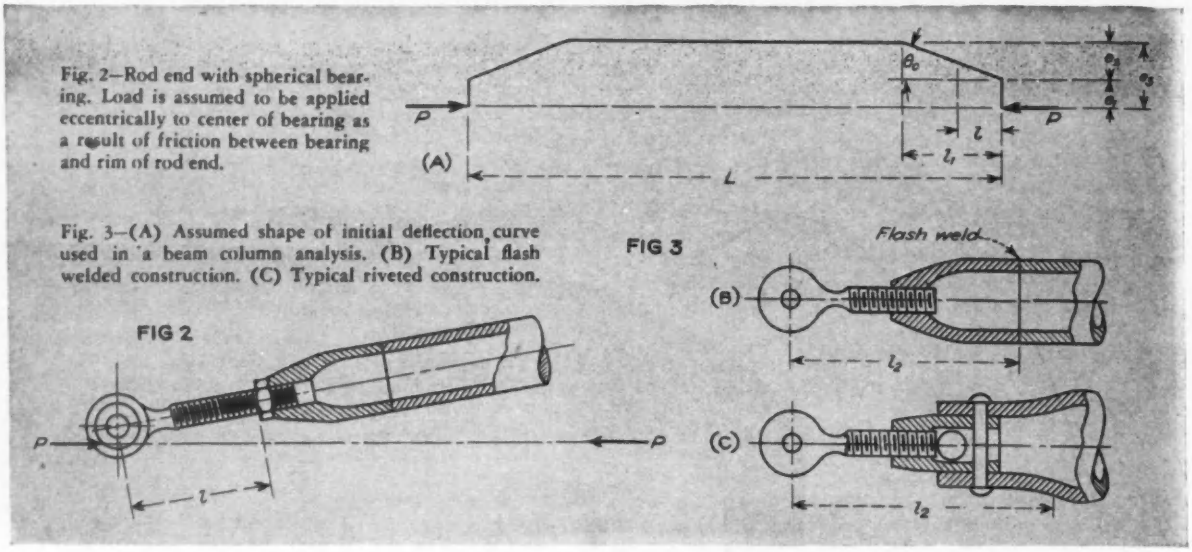

Fig. 2—Rod end with spherical bearing. Load is assumed to be applied eccentrically to center of bearing as a result of friction between bearing and rim of rod end.

Fig. 3—(A) Assumed shape of initial deflection curve used in a beam column analysis. (B) Typical flash welded construction. (C) Typical riveted construction.

the transition piece and attaching it to the tube, and a beam-column magnification factor of 6.

Where

f_a = ultimate applied axial stress, psi
f_b = ultimate applied bending stress, psi
F_{cy} = Compressive yield stress, psi
F_{bu} = modulus of rupture
P = applied load, lb
l = distance from center of bearing in rod end to lock nut as shown in Fig. 1, in.
M = applied bending moment, lb in.
D = nominal diameter of thread on rod end, in.

and from the geometry shown in Fig. 1, the applied bending moment is given by

$$M = 0.157\ Pl$$

and the interaction equation to be used in checking the critical section of the rod end in bending is

$$(f_a/F_{cy}) + (f_b/F_{bu}) = 1$$

The position of the critical section is determined by the length of thread engagement and the thickness of the jam nut. The latter is ordinarily equal to $0.5D$. The length of engagement should be controlled by an inspection hole in the transition piece and should be at least 1.0 D, with 1.25 D desirable. For analyzing the rod end shank, however, it is conservative to assume the engagement to be 1.0 D in all cases.

The foregoing method of analysis is never unconservative; it is recommended for all ordinary applications. A more refined method of analysis, which may be resorted to when it is necessary to justify a higher allowable load for the rod end than given by the foregoing method, is given later in this article.

Male rod ends, such as shown in Fig. 1, are the recommended arrangement. Female rod ends should be avoided, chiefly because the critical section then occurs in the transition piece much farther from the pin, so that the bending moment is greater. If female rod ends must be used, a check for bending should be made similar to that for male rod ends. When threaded rod ends can be avoided altogether, as when length of adjustment is not necessary, it is desirable to do so.

For both external and internal threads, points of stress concentration in the rod end fittings should be avoided by use of thread relief and relief radii. The transition fitting should have a taper to reduce stress concentration in the rod end shank where it enters the fitting.

Where the control rod, or the surface it controls, is subject to vibration, flutter or buffeting, special consideration should be given to the design of the rod. The natural frequency of lateral vibration for all control rods on reciprocating powered airplanes should be determined to preclude synchronism with the engine speed.

WITH SPHERICAL ENDS. The previous discussion on rod ends with anti-friction bearings, applies in full to rod ends with spherical or other plain bearings except that the geometry is as shown in Fig. 2. For ends with spherical bearings, where

d = diameter of bearing sphere, in.

the applied bending moment is given by

$$M = (0.15d + 0.15l)P$$

This equation is based upon an initial angularity θ equal

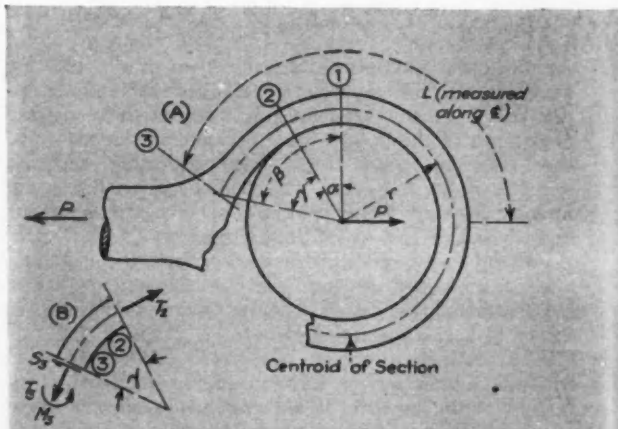

Fig. 4—Loads in necked rod ends. (A) The tangency point is at section 2, to the right of which the load in the rim is pure hoop tension. At section 3, the rim is considered fixed to the shank. (B) Loads on the portion of the rim between point of tangency and the juncture of rim and shank.

to 1.5 deg, a coefficient of friction of 0.3 resulting in an end eccentricity of 0.15 d, an overall beam column magnification factor of

$$\frac{1}{1-(P/P_{cr})} = 3$$

and proportions of the rod assembly as a whole such as to give the most severe beam column action in the rod end.

Allowable Column Load

In determining allowable column load for either type of control rod, it is permissible to treat the rod as a column of uniform EI equal to that of the center portion if unthreaded rod ends or male rod ends are used and the tube itself is of constant section (so that the region of reduced section is very close to the ends) and if the axial stress in the rod ends is in the elastic range. Otherwise the rod should be treated as a stepped column, obtaining P_{cr} using the method described in *NACA Technical Memorandum* 861.

To limit the beam-column magnification factor to the values 6 and 3, which were assumed in the foregoing discussion, it is necessary to provide excess column stiffness. Column adequacy must therefore be checked by using a reduced column allowable obtained from the Euler column formula using an effective value of L/ρ given respectively by:

For rod ends with anti-friction bearings and a beam column magnification factor of 6

$$(L/\rho)_{eff} = 1.1 \times (\text{the geometrical } L/\rho)$$

For rod ends with spherical bearings and a beam column magnification factor of 3

$$(L/\rho)_{eff} = 1.23 \times (\text{the geometrical } L/\rho)$$

When the rod is treated as a stepped column, the equivalent procedure is to obtain P_{cr} using effective values of I given respectively by:

For rod ends with anti-friction bearings and a beam column magnification factor of 6

$$I_{eff} = (1/1.2) \times (\text{the geometrical } I)$$

For rod ends with spherical bearings and a beam column magnification factor of 3

$$I_{eff} = (1/1.5) \times (\text{the geometrical } I)$$

The effective value of P_{cr} thus obtained is regarded as an allowable axial load.

Beam Column Analysis for Rod End Only

The methods of analysis given in preceding paragraphs are to some extent arbitrary and approximate, chiefly because the rod end is considered separately from the rest of the column. For the rod end, the methods are never unconservative and frequently are very conservative. Where a more laborious calculation is justified, a beam column analysis may be made for the actual geometry of the control rod assembly. Such an analysis should usually be made for rod ends of $\frac{1}{2}$ in. and larger pin size.

In a beam column analysis, the initial deflection curve should be assumed to have the shape shown in Fig. 3(A). This shape accounts for the worst eccentricities and angularities in typical construction. If unusual eccentricities are known to be present, the initial deflection curve should be modified to suit.

The letter symbols used in Fig. 3 are defined as follows:

- $\theta_0 = 1\frac{1}{2}$ deg. $= 0.0262$ radians
- $e_2 = 0.0262\, l_1$
- $l_1 = 0.75\, l_2$, where l_2 is measured to the centermost source of angularity in the assembly: as shown in the two typical designs Figs. 3(B) and 3(C). Initial curvature of the tube is neglected.
- $e_1 = 0$ for anti-friction bearings
- $e_1 = 0.15\, d$ for spherical bearings, where d is diameter of the bearing sphere (to account for bearing friction, with a coefficient of friction of 0.3)
- $e_3 = e_1 + e_2$.

For the initial deflection curve shown in Fig. 3(A), bending moments in the rod end at any distance from the center of the bearing (including the critical section) are given with good accuracy by the approximate formula:

$$M = P\left\{e_1 + [0.0262 + 4.93\,(m-1)\,(e_2/L)]\,1\right\}$$

where

$$m = \frac{1}{1-(P/P_{cr})}$$

in which P_{cr} is obtained using the tangent modulus cor-

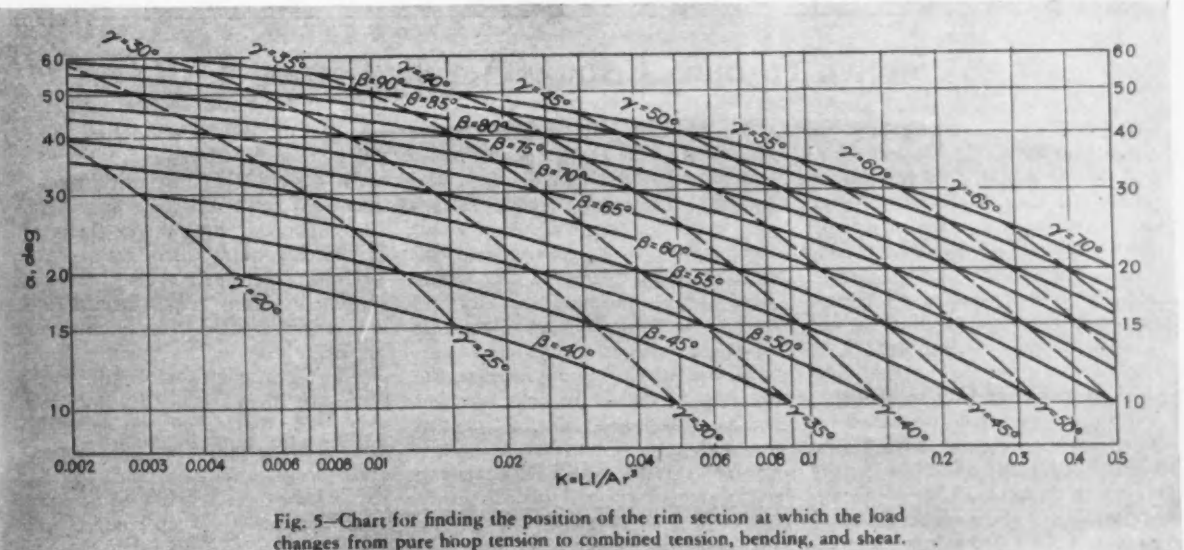

Fig. 5—Chart for finding the position of the rim section at which the load changes from pure hoop tension to combined tension, bending, and shear.

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responding to the applied load P.

For other shapes of initial deflection curve, or if the moment of inertia is not substantially constant, the following more accurate analysis should be used.

1. Assuming the member to be rigid, compute bending moments, and plot an M/EI diagram.

2. Using the graphical method given by Niles and Newell ("Aircraft Structures", 3rd Ed., Vol. 1, pp 249-252), obtain the deflections throughout the member resulting from the M/EI diagram obtained in Step. 1.

3. Multiply these deflections by

$$\frac{1}{1-(P/P_{cr})}$$

(in which P_{cr} is obtained using the tangent modulus corresponding to the applied load P) and add to the original initial deflection curve to give the final deflected shape of the member.

4. Obtain final moments by statics.

Where

f_b' = elastic bending stress resulting from the moment obtained in Step 4
F_{bu} = modulus of rupture
f_c = applied axial stress
F_{cy} = compressive yield stress

the ultimate margin of safety for shank bending is

$$MS = \frac{1}{(f_b'/F_{bu}) + (f_c/F_{cy})} - 1$$

The preceding beam column analysis should be applied only to the rod end (or to the transition fitting if it appears to be critical). In no event should the beam column analysis be used to obtain margins of safety for the tube, as the conservative assumptions introduced into the analysis to provide rod ends of adequate strength would frequently lead to excessive weight of tube. The use of an effective L/ρ in checking adequacy as an Euler column will assure adequate tube strength in all ordinary cases.

Lug Strength

The amount of material required around the bearing of a rod end to prevent tension or shear tear-out failure under tension loading of the rod should be checked by the usual methods of lug analysis (see "Analysis of Lugs and Shear Pins Made of Aluminum or Steel Alloys," F. P. Cozzone, M. A. Melcon, and F. M. Hoblit, PRODUCT ENGINEERING, May 1950, p. 113).

Sharply necked rod ends, such as shown in Fig. 4(A), should also be checked for bending at the juncture of the shank and rim, in Fig. 4(A) this juncture is designated section 3, by the following procedure. In Fig. 4 all angles are in degrees.

1. Compute I and A for section 1, Fig. 4(A)
2. Compute $L = \pi\ r\ [(90 + \beta)/]$
3. Compute $K = (L\ I)/(A\ r^3)$
4. Enter graph Fig. 5 with K and β, then find α and γ where $\gamma = \beta - \alpha$
5. Compute pure hoop tension at section 2, Fig. 4(B) from

$$T_2 = P/(2\cos\alpha)$$

6. Compute loads at section 3, Fig. 4(B), from

$$T_3 = T_2 \cos\gamma$$
$$S_3 = T_2 \sin\gamma$$
$$M_3 = T_3 r\ (1 - \cos\gamma)$$

This procedure has been derived theoretically, assuming a rigid pin and assuming that the increase in length around the rim is given by a tension load T_2 acting upon a member of length L. Within the elastic range, this procedure gives results in close agreement with tests; for example, in checking stresses resulting from fatigue loading against fatigue allowables.

At ultimate load, this procedure can still be used, but will be conservative, where

$$R_b = [M_3/(I/\gamma)_3]/F_{bu}$$
$$R_t = (T_3/A_3)/F_{tu}$$
$$R_s = (S_3/A_3)/F_{su}$$

this procedure should be used in conjunction with the following interaction equation:

$$(R_b + R_t)^2 + R_s^2 = 1$$

whence

$$MS = \frac{1}{\sqrt{(R_b + R_t)^2 + R_s^2}} - 1$$

In addition to an analysis at section 3, if the minimum section of the ring is less than the area of section 3, the minimum section should be checked for pure hoop tension stress with the applied hoop tension load taken equal to T_2 as obtained from Step 5 in the foregoing procedure.

Stretch Forming Reduces Acrylic Crazing

WHILE ACRYLIC PLASTIC GLAZING has been used extensively because of its good weathering and optical properties and its ease of fabrication into shapes or compound curvature, its most serious limitation has been the tendency to craze under stress, especially in the presence of organic solvents. Recent investigations at the National Bureau of Standards have indicated that prestretching the material may improve crazing resistance.

NBS discovered that although biaxially stretch forming the acrylic plastic 50 percent did not affect the tensile strength or secant modulus of elasticity in tension, it did increase the elongation at failure from approxmately 10 percent to about 60 percent.

In addition, the broken tensile specimens of the formed pieces have a laminar character unlike the unformed material. The fracture surface on each of the broken specimens shows that there is a small mirror-like area oriented perpendicularly to the tensile load. They concluded that fracture begins in the mirror area which is an extension of a crazing crack.

Biaxial stretch-forming increases the threshhold stress for stress-solvent crazing with benzene about 75 percent for both general-purpose and heat-resistant grades. And the crazing cracks are finer and more closely spaced than unformed samples.

In long-time tensile loading tests (100 hours), the threshhold stresses for crazing are boosted from 40 to 50 percent by forming.

In designing to take advantage of improved craze resistance and toughness, in acrylic enclosures as the result of stretch forming, there are two possibilities: the material may be prestretched before it is formed into shape, or a more highly stretched enclosure may be designed by forming a larger and more deeply drawn enclosure than required, and then using only the central portion of the formed piece. Either method improves craze resistance; particularly at the rim, where there is likely to be stress concentrations and where contacts with solvents of adhesives used to seal the enclosure may cause solvent crazing.

Glossary of Useful Nuclear Terms

Atomic Mass Unit (a.m.u.)—1.66 x 10^{-24} gram.

Electrostatic Unit (e.s.u.)—A charge equivalent to 2.083 electrons.

Electron—Negatively charged particle with a mass of 9.1 x 10^{-28} gram (5.4862 x 10^{-4} a.m.u), a radius of 2 x 10^{-13} cm, and a charge of 4.8 x 10^{-10} e.s.u.

Million Electron Volts (Mev)—The energy acquired by an electron in falling through a potential of one million volts; equal to 1.603 x 10^{-6} erg.

Extranuclear Electrons—Electrons moving about nucleus in orbits; radius of orbits is about 10^{-8} centimeter.

Proton—Nucleus of hydrogen atom with a positive charge equal to that of the electron (4.8 x 10^{-10} e.s.u.), a mass of 1.660 x 10^{-24} gram (1.00758 a.m.u.).

Neutron (N)—Uncharged particle nearly equal in mass to the proton (1.0089 a.m.u.).

Nucleus—The compact central portion of atoms, composed of neutrons and protons; radius is about 10^{-12} to 10^{-13} centimeter.

Positron—Positively charged particle having same mass and equivalent charge as the electron.

Beta Particle—Electron emitted from nucleus of atom.

Deuteron—Nucleus of heavy hydrogen containing a proton and a neutron.

Atomic Number (Z)—Number of protons in nucleus of an atom; also equal to number of extranuclear electrons.

Mass Number (A)—Sum of the protons and neutrons in the nucleus of an atom.

Half Life—Time required for one half of the atoms in a radioactive sample to decay.

Decay—The change associated with the emission of radiation by a radioisotope.

Curie—That quantity of a radioisotope which decays at the rate of 3.7 x 10^{10} atoms per second.

Ion Pair—A positive and a negative ion as formed in the process of ionization.

Alpha Particle—Nucleus of helium having a mass of 4.00279 a.m.u. and a positive charge of 9.6050 x 10^{-10} e.s.u.

Gamma Ray—Very short wave length electromagnetic radiation; similar to X-rays.

Range—That thickness of material required to absorb completely a particular type and energy of radiation.

A Primer on Radioisotopes

Research programs have indicated a tremendous potential use for radioactive materials in the solution of many and diverse engineering problems. In anticipation of more general industrial application of isotopes, and the need for a better understanding of their characteristics, the authors have included in this article discussions of the following: Types of radiation, methods of isotope production and uses of radioisotopes in the fields of product testing, product control and product improvement.

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PRIOR TO THE OPERATION of nuclear reactors, a few radioisotopes were available from natural sources and cyclotrons, but these materials were costly and available only in limited quantities. Since World War II, the atomic energy programs of this country, Canada and England have produced, largely as by-products, a wide variety of radioisotopes in quantities and at a cost that encourages their use in industry.

Atoms are composed of a compact central nucleus containing neutrons, protons and electrons that move in orbits around the nucleus. In an electrically-neutral atom, the number of protons and electrons are equal as is the case for helium and carbon in Fig. 1(A). These illustrations also define the mass number *A*, which is equal to the sum of the number of protons, or atomic number, *Z*, and the number of neutrons, *N*.

Isotopes are varieties of atoms of the same chemical element, which have the same atomic number, but different mass numbers, Fig. 1(B). Since the chemical properties of all elements are determined by the extranuclear electron structure of their atoms, isotopes of the same element have identical chemical properties, and therefore cannot be separated by chemical means.

All but 23 of the 96 elements occur in nature as mixtures of two or more isotopes. The two naturally-occurring isotopes of carbon are shown in Fig. 1(B). Only difference between the atoms of these two isotopes is that carbon-13 contains one more neutron. Carbon found in nature contains 98.9 percent carbon-12 and 1.1 percent carbon-13, neither of which is radioactive.

Radioactive isotopes are unstable forms of the elements which emit energy in the form of radiation. They are unstable because their nuclei contain numbers of protons and neutrons in quantities such that they cannot form stable configurations. Fig. 1(C) shows two carbon radioisotopes, carbon-11 and -14.

The atoms of radioisotopes emit energy or decay at characteristic rates, and in so doing become more stable. The rate of decay is exponential and is conveniently defined in terms of a half life. This is the time required for one half of the atoms in a particular sample of a radioisotope to decay. The half lives of different iso-

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topes vary from microseconds to many thousands of years. For example, the half life of carbon-11 is 21 min and of carbon-14 is about 5,700 years. In the case of carbon-11, starting with 100,000 atoms, the following decay schedule would be expected:

No. of Atoms Left	Time, min
100,000	0
50,000	21
25,000	42
12,000	63
6,250	84

Types of Radiation

The radiation emitted by atoms of radioisotopes is of several different types. There are *alpha particles, beta particles, positrons, X-rays, (K-electron capture process)* and *gamma rays.*

An *alpha particle* is the nucleus of a helium atom (see Fig. 1) that has lost its two panetary electrons, and is therefore positively charged. Each alpha particle has two protons and two neutrons, a mass of 4.00279 a.m.u. (atomic mass unit), and a positive electric charge which is numerically the double of the electronic charge, i.e., about 9.6050 x 10^{-10} e.s.u. (electrostatic unit). Alpha particles are ejected by certain radioactive substances (particularly the heavy elements such as uranium, thorium, radium) and, while the velocity, range, energy and the number of particles emitted vary according to the emitting substance, particles, emitted by a homogeneous radioactive substance have the same range and speed. Their velocities vary between 1.4 and 2.0 x 10^9 cm per sec, their energies up to 10.5 Mev (million electron volts), according to the emitting substance.

While alpha particles are limited in range to about 8.6 cm in air (their penetration power is so low that a sheet of paper can stop them), they cause dense ionization in the air along their path—a single alpha particle can produce 20,000 to 40,000 ion pairs along its path. In the cloud chamber, alpha particles show straight tracks as illustrated in Fig. 3.

The process of alpha emission can be represented by a nuclear equation. In the case of polonium-210,

$$\underset{\text{polonium}}{{}_{84}Po^{210}} \rightarrow \underset{\substack{\text{particle}\\\text{alpha}}}{{}_{2}He^{4}} + \underset{\text{lead}}{{}_{82}Pb^{206}}$$

For the left hand term of this equation, the superscript 210 denotes the mass number *A*, and the subscript 84 the atomic number, *Z*. Through the process of alpha emission, polonium-210 decays to lead-208, which is a stable isotope.

A beta particle is a negatively charged particle, or electron, ejected at high velocity from the nucleus of the atom of a radiosotope when one of its neutrons changes into a proton. One and the same homogeneous radioactive element emits beta particles of different energies, velocities and ranges. The velocity can be very high, up to 99.8 percent of the speed of light, the energy to about 3 Mev, and the range to a power sufficient to penetrate slightly less than 2 mm of brass or slightly less than a millimeter of lead or silver. Thus beta particles are more penetrating than alpha particles, but less so than gamma rays. Their ionizing power, too, is far less than that of the alpha particle; fast beta particles produce only 50-100 ion pairs per cm of their path, expending about 60 ev of their energy in each pair-producing collision. The mass of beta particle is 5.4862 x 10^{-4} a.m.u., consequently the emission of a beta particle leaves the mass number unchanged, but causes the atomic number of the emitting nucleus to increase by *one,* and thus a net increase of the total positive charge of *one.* Beta particles leave crooked paths in the cloud chamber.

The process of beta decay can also be symbolized as a nuclear equation. In the case of strontium-90,

$$\underset{\text{strontium}}{{}_{38}Sr^{90}} \rightarrow \underset{\substack{\text{beta}\\\text{particle}}}{{}_{-1}e^{0}} + \underset{\text{yttrium}}{{}_{39}Y^{90}}$$

Here, yttrium-90 is also radioactive and decays by beta emission as follows:

$$\underset{\text{yttrium}}{{}_{39}Y^{90}} \rightarrow \underset{\substack{\text{beta}\\\text{particle}}}{{}_{-1}e^{0}} + \underset{\text{zirconium}}{{}_{40}Zr^{90}}$$

The strontium-yttrium-zirconium relationship is known as a radioactive series in which yttrium is a radioactive daughter of strontium and zirconium is a stable daughter of yttrium.

A *positron* is a sub-atomic particle identified as a positively charged electron. It is exactly identical with an electron in atomic weight (5.4862 x 10^{-4} a.m.u.), and its positive charge is equal to the numerical value of the negative charge of the electron (4.8025 x 10^{-10} e.s.u.). Positrons are extremely short-lived particles, capable of existence only while in motion. As soon as they come into the vicinity of electrons, they combine with the latter to form gamma (annihilation) ra-

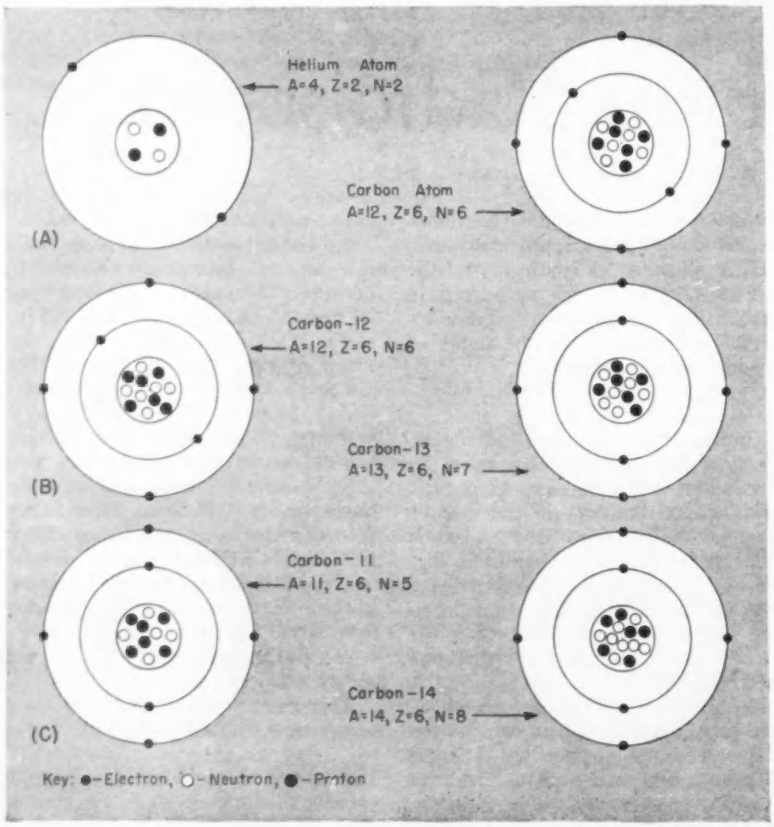

Fig. 1—(A) Atomic structure is based on the Bohr theory of a central nucleus with orbital electrons. (B) Stable isotopes of carbon. (C) Radioactive (unstable) isotopes of carbon. Mass number *A* is sum of atomic number *Z* and number of neutrons *N*.

Brookhaven National Laboratory

Fig. 2—Sixty-inch atom-smasher is the "work horse" of cyclotrons used for accelerating the lighter positive nuclear particles to produce radioisotopes. Man at right is setting the frequency of the cyclotron, while man at the rear is adjusting the ion source.

diation. Positrons are observed principally in cosmic radiation, and also in the radiation of certain unstable radioisotopes.

The equations for positron emission are exemplified by copper-64:

$$_{29}Cu^{64} \rightarrow {}_{1}e^{0} + {}_{28}Ni^{64}$$

copper → positron + nickel

and the annihilation reaction,

$$_{1}e^{0} + {}_{-1}e^{0} \rightarrow \gamma$$

positron + electron → gamma ray.

K-electron capture is a radioactive nuclear transformation. An unstable nucleus reduces its nuclear charge and atomic members by *one* to achieve stability by drawing an extranuclear electron from the K-shell (inner electron shell) into the nucleus where this electron unites with a proton, forming an new neutron. To effect the transition from this excited stage to the normal state, the electron captured from the K-shell is replaced by an electron from another shell. This change is accompanied by the release of a quantum of radiant energy, called *K* X-ray. The same reduction of the nuclear charge, i.e. of the atomic number by *one*, can be accomplished by positron emission. Heavier nuclei have a tendency to reduce their nuclear charge by K-capture, lighter nuclei by positron emission.

The process of K-capture is represented by a nuclear equation, which for iron-55 is,

$$_{26}Fe^{55} \rightarrow {}_{1}e^{0} + {}_{25}Mn^{55}$$

iron → positron + manganese

A *gamma-ray* is an electromagnetic radiation of nuclear origin of very short wavelength emitted by the nuclei of certain atoms in the course of their radioactive decay. They have the speed of light, no electric charge and no "at rest" mass, but do have a very slight mass due to their motion and velocity. Their range, both in air and matter, is much longer than that of either alpha or beta particles, but their ionizing capacity is much weaker than that of either of the latter. Gamma rays produce an average of only 1.5 ion pairs per centimeter of their path. As to wavelength and penetration power, they occupy an intermediate position between X-rays and cosmic rays. The wavelength of the gamma ray is characteristic of the element emitting it, and varies between 0.0466 and 3.9 angstrom units.

Being electromagnetic in nature and having zero charge, gamma rays are not affected by electric or magnetic fields. They can be detected in the cloud chamber because they impart their energies to electrons which produce secondary ionization.

Gamma radiations usually occur in close association with the emission of alpha and beta particles. They are a highly dangerous radiation, and due to their long range and high penetration power, the importance of protective measures cannot be overemphasized. Exposure to any type radiation can destroy living cell tissues, produce sterility or hereditary mutations in humans, according to the dosage; and exposure to an extreme dosage can result in instantaneous death. On the other hand, the cell-destroying capacity of gamma rays makes them suitable for controlled medical use in the treatment of malignant growths.

No matter what the type of emission, radioisotopes should be treated with extreme care.

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Production of Radioisotopes

Radioisotopes are produced by the nuclear fission process (fission products), by neutron irradiation in a nuclear reactor (pile-produced), or in nuclear accelerators such as the cyclotron (cyclotron produced).

Fission products are radioisotopes that are produced as a by-product of the operation of nuclear reactors. When uranium-235 undergoes fission, it emits neutrons (needed for the production of plutonium) and splits into fragments. These fragments or fission products are frequently radioisotopes of elements near the middle of the periodic table (mass numbers from about 72 to 162). They represent the largest quantities of radioisotopes produced. Some of the important isotopes in this group are strontium-90, cesium-137 and cerium-144.

Pile-produced isotopes are obtained by various nuclear reactions in a nuclear reactor. The processes are based on the fact that a variety of stable isotopes can be converted to radioisotopes by irradiation with neutrons. Radioactive cobalt-60 is produced by irradiating stable cobalt-59 with neutrons:

$$_{27}Co^{59} + {}_{0}n^{1} \rightarrow {}_{27}Co^{60}$$
cobalt − 59 neutron cobalt − 60

More complicated reactions are used to produce other radioisotopes. Nitrogen-14 is irradiated with neutrons to produce carbon-14:

$$_{7}N^{14} + {}_{0}n^{1} \rightarrow {}_{6}C^{14} + {}_{1}H^{1}$$
nitrogen neutron carbon proton

Phosphorus-32 and sulfur-35 are produced in a similar way.

Cyclotron-produced isotopes are extremely important because there are many useful radioisotopes which are obtainable only from a cyclotron. This equipment can be used to irradiate samples of protons, alpha particles, deuterons and electrons. For example sodium-22 is produced from magnesium,

$$_{12}Mg^{24} + {}_{1}H^{2} \rightarrow {}_{11}Na^{22} + {}_{2}He^{4}$$
magnesium deuteron sodium alpha particle

Uses of Radioisotopes

A radioisotope being a radioactive form of an element, when a small quantity of the radioisotope is added, the course of the parent metal or its compound can be traced with a Geiger counter or similar instrument. This tracer technique is one of the major uses of radioisotopes, and the important characteristic of this work is the sensitivity of detection which permits measurements to one million millionth of an ounce of some materials.

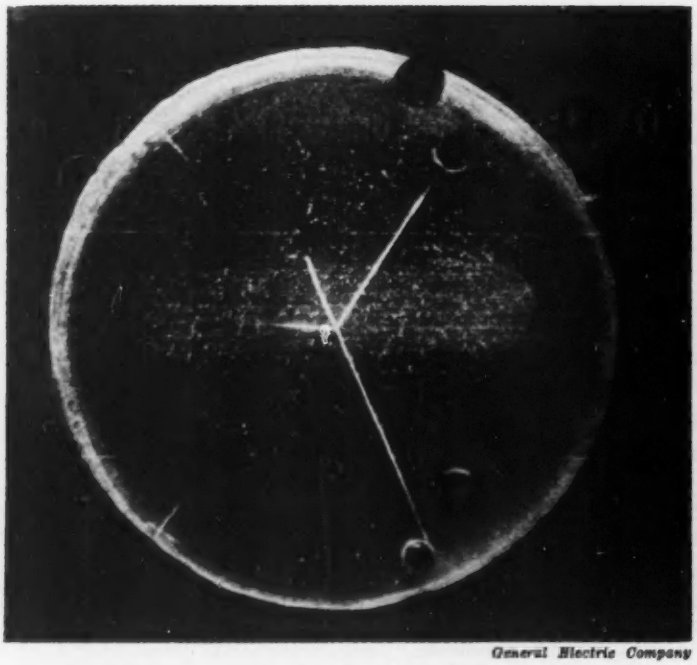
Other applications of radioactive materials utilize the effect of the energetic radiations on matter or the effect of matter on the radiations. In the former case, radioactivity is the source of energy for activating a chemical reaction; in the latter case, it can be used to measure the thickness of sheet material. Table I is a list of radioisotopes and some of their applications.

Product-Testing Applications

Wear and lubrication. Investigations of friction, wear and lubrication have become important applications of radioisotopes. In a study of the wearing qualities of electrical contacts, one of the contacts is made radioactive with an isotope of the base material. The quantity of radioactive material transferred to the non-radioactive contact is a measure of the amount of wear. An important factor in this type of test is that wear between two electrodes constructed of the same metal can be evaluated in a simple, yet accurate manner.

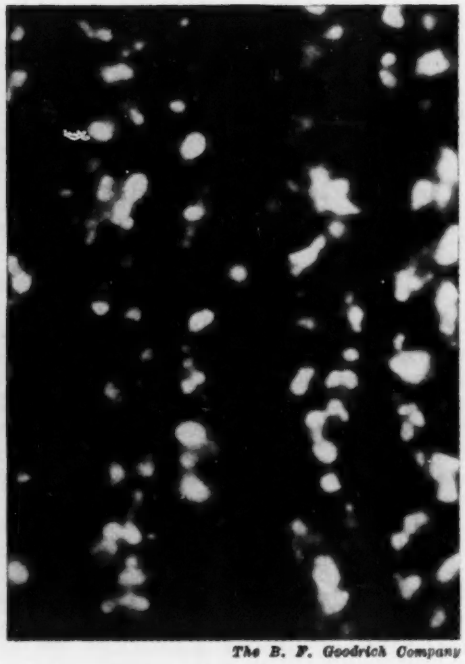
The wearing qualities of protective coatings, such as waxes and paints, can be tested in a similar way. A small amount of a suitable radioactive isotope is mixed with the protective coating which is applied to the test specimen. The amount of coating material removed during simulated conditions of wear is then measured.

In evaluating the efficiency of lubricants, metal parts, such as bearings, shafts and gears, being protected by the lubricants are "labeled" with the radioactive isotope of the metal in-



General Electric Company

Fig. 3—Cloud chamber tracks show the disintegration of an oxygen nucleus into four alpha particles. This reaction is produced by X-rays in a 100-Mev betatron and high-speed photography used to show pattern.



The B. F. Goodrich Company

Fig. 4—Accelerated wear test of automobile tire tread. Beta-emitting Phosphorus 32 in tire track left on asphalt pavement after rapid stop shows abrasion

volved. The amount of metal detected in the oil system is a measure of the effectiveness of the lubricant. This is a very good illustration of the much-publicized tracer technique.

Similar techniques may be developed for the many products constructed or coated with metal, rubber, plastics or paint. The advantages of such tests are that extremely small quantities of wear can be detected, and prolonged tests are not required to evaluate wear and lubricating qualities.

Radiography. X-ray machines have had wide application in nondestructive test methods for locating flaws and foreign objects in a variety of products. The gamma rays emitted by cobalt-60, for example, are similar to X-rays and can be used in place of X-rays for some radiographic tests. The advantages are that gamma rays are more energetic and penetrating than the X-rays available in many laboratories and that sources of the radioisotopes are smaller than X-ray tubes, thus easing placement of the source inside small parts. For many applications, radiography with radioisotopes is more satisfactory and less costly than other methods.

Motion Studies. It is possible to study the motion of solids, liquids and gases by means of radioisotopes. The motion of a concealed part in an engine can be studied by attaching a radioactive source to the part. Through the use of a radioisotope that emits penetrating gamma rays, it is possible to locate and measure the motion of the part through several inches of metal.

The flow of liquid through a complicated system of pipes, for example, water through boiler tubes, can be traced with radioactive materials. For studies of this type, a small quantity of a soluble form of one of the radioisotopes is added to the inlet stream. The position and rate of flow of the radioactive liquid through the tubes is then determined.

Radioactive techniques should prove valuable for checking the efficiency of laundry equipment. Standard tests involving fabrics soiled with radioactive dirt could be devised to measure cleaning efficiency as a function of equipment design.

Similar application of radioisotopes is possible in the case of gases. Radioactive carbon dioxide, sulfur dioxide, argon, xenon, and krypton can be applied to leak detection, studies of air flow through ducts, and tests to discover the distribution of air jetted into a boiler or furnace.

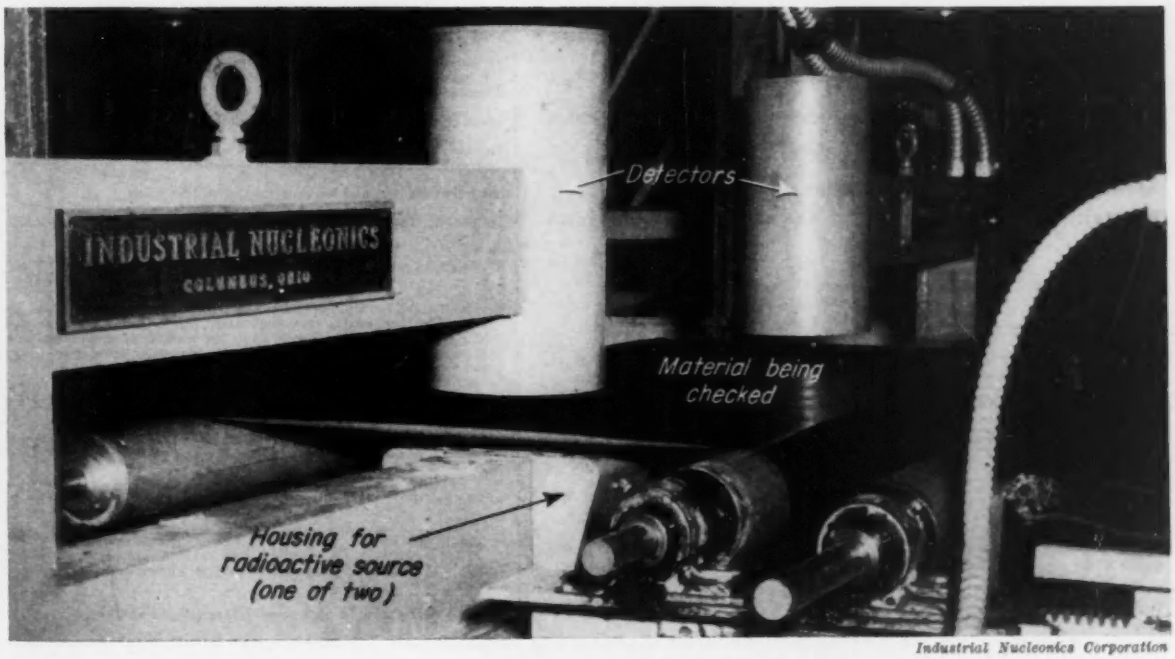
The efficiency of air filters or vacuum sweepers can be determined with radioisotopes. Dirt or dust of various particle sizes is "labeled" with a radioactive material. This facilitates measurements of the stopping power of a filter or the collection efficiency of a vacuum system for a specific range of particle sizes.

Product-Control Applications

Thickness Measurements. Radioactive thickness gages have recently become commercially available. The basic components of these units are a radioisotope source, a device for detecting radioactivity and a recorder. Radioactive rays are absorbed in proportion to the weight per unit area of the material placed between the source and the detector. If the material has a constant density, the thickness can be measured directly.

Radioactive thickness gages are now used to monitor and control the thickness of thin sheets of rubber, plastic, paper, metal and cloth. The devices operate automatically and nondestructively, Fig. 5, for continuous thickness measurements to an accuracy of about one percent. Gages for the measurement of the thickness of protective coatings on base materials and for thick specimens are also available.

Density Measurements. Rays from radioisotopes are utilized for density or specific gravity measurements. Absorption of the radiation from radioisotopes is proportional to the mass of material per unit area. If the thickness of the specimen is known, the density is then determined directly. Scattering



Industrial Nucleonics Corporation

Fig. 5—Two radioactive thickness gages continuously monitor sheet stock during processing. Strontium 80 is the source material from which beta particles radiate upward through sheet to detectors. Recorder tallies counts in terms of thickness. This method of nondestructive testing is being used more and more for reducing cost of producing many different types of material.

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Table I—Typical Applications of Radioisotopes

Element and Isotope[1]	Half life[2]	Radiation, mev[3]		Industrial Applications
		Beta[4]	Gamma[5]	
Antimony Sb 122	2.8d	1.94	0.568	To study the rate of exchange between Sb(III) and Sb(V); to study the mechanism of glass formation; as pipeline tracers.
Sb 124	60d	2.37	7 γ's, 0.121 $<E\gamma<$ 2.3	
Sb 125	2.7y	0.616	7 γ's, 0.035 $<E\gamma<$ 0.637	
Argon A 37	34.1d	K(6)	None	To determine the optimum conditions for separating argon from other gases.
Arsenic As 76	26.8h	3.12	5 γ's, 0.567 $<E\gamma<$ 2.3	To investigate the mechanism of glass formation; to detect small quantities of arsenic vapor in air; to determine the rate of corrosion or arsenical brass.
As 77	40h	0.7	None	
Barium Ba 131	12d	K	3 γ's, 0.26 $<E\gamma<$ 1.2	To trace the flow of oil through pipelines; to determine the action of detergents on sludge forming oxy-acids produced by oxidation of lubricating oils.
Ba 140	12.8d	1.02	3 γ's, 0.160 $<E\gamma<$ 0.540	
Bismuth Bi 210	5.0d	1.17	None	To study the deposition of thin films of bismuth.
Bromine Br 82	36.0h	0.465	7 γ's, 0.55 $<E\gamma<$ 1.31	To study exchange reactions such as Br 82 with CCl_3Br; to determine the amount of bromides adsorbed by fibers from solutions.
Cadmium Cd 109	330d	K	0.088	To study characteristics of phosphors; as an analytical tool in process and product control.
Cd 115	2.3d	1.1	0.34 $<E\gamma<$ 0.52 (4.5h In 115)	
Cd 115	43d	1.67	0.5	
Calcium Ca 45	180d	0.254	None	To determine the diffusion coefficient in glass.
Carbon C 14	5,740y	0.154	None	To study catalytic processes such as the Fischer-Tropsch synthesis; to study metallurgical problems such as the diffusion and concentration of carbon in steel; as radiation sources for thickness gages used to continuously monitor films of material.
Cerium Ce 141	28d	0.56	0.141 $<E\gamma<$ 0.315	As a tool to determine the concentration of cerium in phosphors; process-rate measurement.
Ce 143	33h	1.36	0.5	
Ce 144	275d	0.3	None	
Cesium Cs 131	10.2d	K	None	To study abrasion of rubber and various plastics; used as radiation sources for radiography and teletherapy units.
Cs 134	2.3y	0.658	4 γ's, 0.568 $<E\gamma<$ 1.35	
Cs 137	37y	1.2	0.662	
Chlorine Cl 36	4.4×10^5y	0.71	?	As an analytical tool for the determination of small quantities of chlorides in paper pulp after washing; to study the corrosion of stainless steel by salt water.
Chromium Cr 51	26d	K	0.267 $<E\gamma<$ 0.32	To study the transfer of material between rubbed surfaces, and the electrodeposition of chromium.
Cobalt Co 60	5.2y	0.31	1.17 and 1.33	To investigate the cause of paint blisters; to radiograph thick sections of metal—equivalent to a 2,000-kv X-ray machine; to study the permeability of naturally occurring or artificially produced porous media to the flow of oil, gas and water mixtures.
Copper Cu 64	12.8h	0.65	1.34	To study self-diffusion in stressed copper; to determine the mechanism of the oxidation of copper at high temperatures; to determine friction characteristics of copper alloys.
Europium Eu 152	5.3y	1.7	0.3 $<E\gamma<$ 1.2	To determine the concentration of europium in phosphors; for radiography of thin sections of materials.
Eu 154	5.4y	1.9		
Gallium Ga 72	14.25h	3.17	9 γ's, 0.631 $<E\gamma<$ 2.18	To study the effects of impurities in germanium.
Germanium Ge 71	11.4d	K	None	As an analytical tool in process and product control; to study the effect of distribution on electric properties in a semiconductor.
Ge 77	12h	1.74	0.5	
Gold Au 198	2.69d	0.97	0.411	To investigate analytical problems in the photographic-film industry; to study thickness of film deposited by high-temperature vaporization of gold.
Au 199	3.3d	0.32	6 γ's, 0.024 $<E\gamma<$ 0.23	
Hafnium Hf 181	46d	0.405	5 γ's, 0.087 $<E\gamma<$ 0.480	As an analytical tool in process and product control.
Hydrogen H 3 (Tritium)	12.5y	0.0189	None	To study process rate measurements, and investigate the mechanism of various chemical reactions.
Indium In 114	50d	I.T.(7)	0.192	For tracer studies, and to study rate of self-diffusion.
Iodine I 131	8.0d	0.60	5 γ's, 0.080 $<E\gamma<$ 0.638 (12.0d Xe 131)	To measure the thickness of thin films of rubber of the order of one micron.
Iridium Ir 192	70d	0.67	12 γ's, 0.137 $<E\gamma<$ 0.651	As a gamma ray source for radiography.
Ir 194	19h	2.18	0.38 $<E\gamma<$ 1.43	
Iron Fe 55	2.91y	K	None	To make diffusion studies in steel in relation to such phenomena as annealing, hardening, recrystallization, grain growth, creep, and high-temperature behavior; to study the transfer of small quantities of metal between bearing surfaces; to study the corrosion of iron and steel.
Fe 59	46.3d	0.46	1.1 and 1.3	
Lanthanum La 140	40.4h	2.26	7 γ's, 0.093 $<E\gamma<$ 2.9	For radiographic inspection where only a few radiographs are required; as an analytical tool in process and product control.
Mercury Hg 197	65h	K	0.077	As an analytical tool for the purification of silver; to determine small amounts of mercury vapor in air—as low as 10^{-9} gram.
	25h	K	4 γ's, 0.135 $<E\gamma<$ 0.286	
Hg 203	43.5d	0.205		
Molybdenum Mo 99	68.3h	1.22	3 γ's, 0.141 $<E\gamma<$ 0.360 (5.9h Tc 99?)	As an analytical tool in process and product control.
Neodymium Nd 147	11d	0.78	(γ or X-ray)	For tracer studies.
Nickel Ni 59	2×10^5y	K	None	To study the magnetic properties of magnet alloys, and the passivity of iron.
Ni 63	85y	0.06		
Niobium Nb 95	90h	I.T.	0.216 and 0.758	To study segregation in high-temperature alloys and steel.
	35d	0.146		

(1) Reactor-produced radioisotopes procurable through the U. S. Atomic Energy Commission.
(2) y—years, d—days, h—hours.
(3) Million electron volts.
(4) When a beta spectrum is known to be complex, only the maximum energy of beta radiation is given. For complete data, see *Nuclear Data* published by the National Bureau of Standards, Washington, D. C., Circular 499.

Element and Isotope[1]	Half life[2]	Radiation, mev[3]		Industrial Applications
		Beta[4]	Gamma[5]	
Osmium Os 185	97d	K	0.648 < Eγ < 0.878	Tracer analysis for osmium.
Os 191	15d	0.142	0.039 < Eγ < 0.127	
Os 193	32h	1.10	0.14e⁻(?) < Eγ < 1.58(?)	
Palladium Pd 103	17d	K	None	For tracer studies.
Pd 109	13.1h	0.95	None	
Phosphorus P 32	14.3d	1.712	None	To improve abrasion test for evaluating tire wear; to determine the rate at which phosphorus reaches equilibrium between slag and steel; and to ascertain the film thickness of printing ink.
Platinum Pt 197	18d	0.65	None	To control the thickness of platinum plating on ceramic ware.
	82d(?)	0.54	0.6	
Polonium Po 210 (8)	140d	5.298[9] (alpha)	0.8 (weak)	To dissipate electrostatic charge formed on cloth, paper, and other materials during the manufacturing process.
Potassium K 40 (8)	1.4×10^9y	1.4	1.5	As an analytical tool for the determination of potassium.
Praseodymium Pr 142	18.9h	2.23	5 γ's, 0.329 < E < 1.59	As a source of gamma radiation for radiography, and in tracer studies.
Pr 143	13.8d	0.92	None	
Promethium Pm 147	2–4y	0.223	None	For tracer studies, and as a source of pure beta radiation.
Pm 149	47h	1.1	0.25 (weak)	
Radium Ra 226 (8)	1,620y	4.61 & 4.79 (alpha)	0.19	To dissipate electrostatic charge, and to produce luminescent print.
Radon Rn 222 (8)	3.82d	5.49		To study the effect of alpha radiation on chemical reactions.
Rhenium Re 186	92.8h	1.09	3 γ's, 0.132 < Eγ < 1.7	For tracer studies.
Re 188	18.9h	2.10	5 γ's, 0.15 < Eγ < 1.43	
Rhodium Rh 105	36.5h	0.78	0.33	For tracer studies.
Rubidium Rb 86	19.5d	1.82	1.081	To evaluate ion-exchange resins.
Rb 87 (8)	6×10^{10}y	0.13	0.13	
Ruthenium Ru 97	2.8d	K	0.22	For tracer studies.
Ru 103	42d	0.684	0.494	
Ru 106	1.0y	0.041	None	
Samarium Sm 153	47h	0.80	3 γ's, 0.069 < Eγ < 0.6	To evaluate trace impurities of samarium in phosphors.
Scandium Sc 46	85d	1.49	0.89 < Eγ < 1.12	For tracer studies.
Selenium Se 75	127d	K	10 γ's, 0.067 < Eγ < 0.405	For making radiographs of moderate section thickness—equivalent to a 250-kilovolt X-ray machine, and to determine the fluid saturation of permeable cores in oil-field research.
Silver Ag 110	270d	0.53	8 γ's, 0.676 < Eγ < 1.516	To investigate the exchange between solid silver and a solution containing a very small concentration of silver; to study the passivity induced to an iron surface; and to investigate the electrodeposition of silver.
Ag 111	7.5d	1.06	None	
Sodium Na 24	14.9h	1.39	1.38 < Eγ < 2.758	To measure the diffusion of sodium into a soda lime glass; and determine the efficiency of dealkalization of glass surfaces.
Strontium Sr 89	53d	1.50	None	As a source of radiation for thickness gages; to dissipate electrostatic charges; to study oxytocic properties of strontium; as a source of radiation for stimulation of phosphors; to evaluate ion-exchange resins.
Sr 90	25y	0.537	None	
Sulfur S 35	87.1d	0.167	None	To investigate the mobility of adsorbed gaseous films on solid surfaces; to study the mechanism of the vulcanization of rubber; to determine the "oiliness" of oils.
Tantalum Ta 182	117d	0.53	33 γ's, 0.0462 < Eγ < 1.237	Can be substituted for radium in radiographic work where a short half life is not a handicap; as a beta-ray source for thickness gage.
Technetium Tc 97	90d	I.T.	0.097	To determine the role of technetium in phosphors.
Tc 99	3×10^5y	0.3	None	
Tellurium Te 127	90d	I.T.	0.089	For tracer studies.
	9.3h	0.8	None	
Te 129	32d	I.T.	0.106	
Te 131	1.25d	I.T.	0.177	
Thallium Tl 204	2.7y	0.783	None	As a source of beta radiation for thickness gages; to study the color of inorganic compounds and the relation of color to the oxidation state of the element.
Tin Sn 113	112d	K	0.09	To study the nature of chemical bonding between atoms; to evaluate the color of inorganic compounds and the relation of color to the oxidation state of the element; and to determine the distribution and effects of small quantities of tin in a semiconductor.
Sn 121	1.1d	0.35	None	
Sn 123	130d	1.3	None	
Tungsten W 185	73.2d	0.43	0.134(?)	To determine the properties of high-temperature alloys such as those used in gas turbines.
W 187	24.1h	1.318	5 γ's, 0.078 < Eγ < 0.650	
Xenon Xe 131	12.0d	I.T.	0.165	To determine the optimum conditions for separating the gas from contaminants.
Yttrium Y 90	61h	2.18	None	As a source of pure beta radiation for thickness gages.
Y 91	57d	1.537		
Zinc Zn 65	250d	K	1.11	To study the swelling properties of cellulose fibers; to determine the vapor pressure of the metal under various conditions, and to observe self-diffusion under conditions of stress.
Zn 69	13.8h	I.T.	0.439	
Zirconium Zr 95	65d	0.887	0.708	For tracer studies; to study flow of heavy petroleum products in pipe lines, and measure rate of catalyst circulation in catalytic petroleum plant.
Zr 97	17h	2.2	0.8	

(5) Detailed information for gamma spectrum of each isotope can be found in *Nuclear Data*.
(6) K electron capture—weak gamma radiation.
(7) Internal transition.
(8) Naturally occurring.
(9) No beta emission.

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or reflection of the rays is also used to determine the density or specific gravity of a material. For example, the amount of scattering is proportional to the specific garvity and composition of a solution.

Purity Measurements. There are various ways in which radioisotopes are applied for measuring the purity of a product. One method consists of adding a radioactive form of the impurity or impurities to the raw material during the processing of the product. The impurities are then traced, since the radioactive form of the impurity follows the impurity during any operation.

Another method involves the activation of the impurity in the finished product by irradiation with neutrons. This procedure is not generally available, because a satisfactory source of neutrons requires a cyclotron or nuclear pile. However, the method is useful for determining the extent of contamination by trace impurities or materials that are difficult to analyze by conventional procedures.

Irradiation by neutrons produces radioactive forms of impurities which permit identification and determination of contaminants. This is possible since radioisotopes decay at characteristic rates by the emission of radiations having characteristic energies.

Homogeneity Measurements. When a suitable radioactive material is added to a material being mixed, the homogeneity of product is readily determined. Measurements of the radioactivity in selected samples of the mixture indicate the completeness of the mixing and the degree of homogeneity.

Product Improvement Applications

Metal Products. The metal industries have found radioisotopes useful for solving a variety of problems. In developing methods for cleaning metal surfaces, radioactive forms of the impurities being removed afford an extremely sensitive measure of the process efficiency. Applications are also made in studies of corrosion. Radioactive forms of various metals are used to obtain data on rates of corrosion in different solutions.

Soldering and welding problems can also be solved with radioisotopes. The amount of metal transfer between two pieces of metal, whether similar or dissimilar, is determined as for electrical contacts by using one piece of metal containing a small amount of radioisotope of the metal. The effect of fluxes can thus be evaluated.

Protective Coatings. Radioisotopes are important research tools in investigations of electroplating. Additives are frequently used in baths to produce a particular type of finish. Little is known concerning the mechanism of additives, basic information concerning their function can be obtained by tracer techniques.

Radioactive materials could be used in studies of coatings used to inhibit corrosion. It is important that temporary coatings applied to metal parts for protection during storage and shipment completely cover all exposed surfaces. Techniques and equipment required to accomplish this could be developed with the aid of radioactive "labeled" coatings that indicate uniformity and continuity of the coating.

Electrical Equipment. In addition to the electrical contact wear tests mentioned above, other radioisotope applications may be found in equipment utilizing spark discharge. The regularity of the firing of metal spray guns can be improved by ionizing the air in the spark gap. This is accomplished by irradiating the air and producing a more uniform resistance path for the voltage discharge.

Graphic Arts. This industry may benefit from the application of radioactive materials to investigations of printing ink transfer. Studies of this nature could be made as a function of machine design, ink composition or paper characteristics.

Many of the problems associated with the handling of paper products result from electrostatic charges. Radioactive static eliminators have been used for many years to neutralize static charges and most of these devices utilize naturally occurring radioisotopes such as polonium. The alpha rays emitted by these isotopes have a very low power to penetrate materials. As a result, only an extremely thin membrane is used to cover and hold the radioactive material. When beta particle emitters, which penetrate thicker layers of material, are used the isotopes are mounted in hermetically sealed capsules to reduce contamination.

Limitations of Radioactive Techniques

Radioisotopes are not a cure-all for industrial problems. While there are some unique uses, such as accelerated wear testing of tire treads, Fig. 4, in most cases there are other methods of solving a problem. Radioisotope techniques should be applied after research or development work has indicated that there is some advantage over other techniques.

Some desirable uses of radioisotopes have been delayed as a result of a potential health hazard from the radiations. Many of these obstacles currently retarding the industrial use of radioisotopes will be removed as additional trained personnel become available and specialized equipment is perfected.

Fig. 6—Geiger counter is generally used to measure the radioactivity of a sample.

REFERENCES

(1) Samuel Glasstone, "Sourcebook on Atomic Energy", D. Van Nostrand Co., 1950.

(2) Stanford Research Institute, "Industrial Uses of Radioactive Fission Products".

(3) G. D. Calkins, "Industrial Applications of Radioisotopes", *Chemical and Engineering News*, 1951.

(4) University of Michigan, "Lectures Presented at Training Course in Radiological Safety", 1951.

Using University Facilities For Industrial Research

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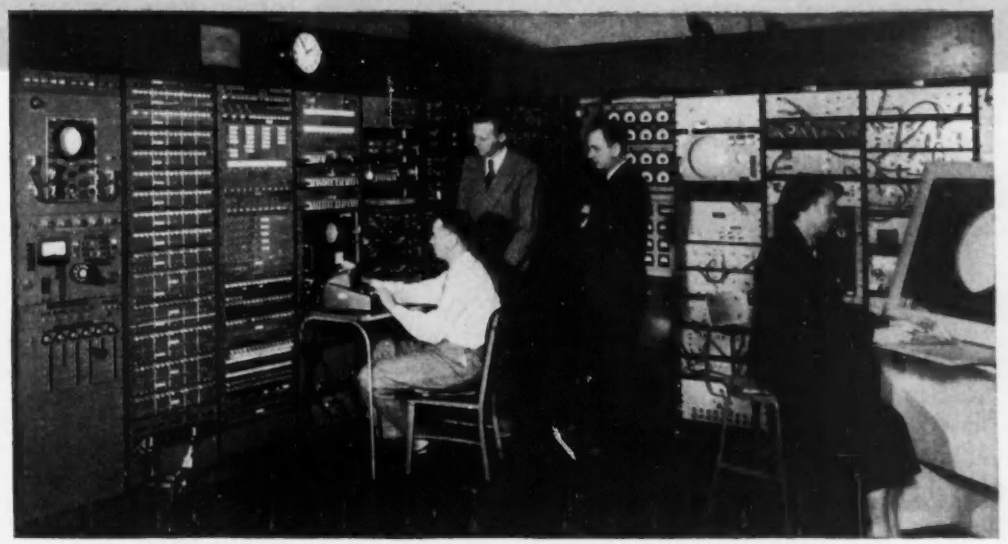

OPERATION CENTER for Whirlwind I, the high-speed electronic computer at the Massachusetts Institute of Technology. Unit has a built-in memory, and delivers information at the rate of 20,000 times a second.

ONLY FIFTY YEARS AGO, research was considered almost exclusively the property of the university. In those early days, research in universities was generally understood to be fundamental or basic in character, although much of it could rightly have been called "applied" research, the type of greatest interest to most industrial concerns.

The telegraph was developed by Professor S. F. B. Morse, of New York University; the aluminum industry, by Charles M. Hall, a student at Oberlin College; and the regenerative circuit in radio, by Edwin H. Armstrong, a student at Columbia University. More recently, practical wire recording was launched by Marvin Camras, a student at Illinois Institute of Technology; Nieuwland's work at Notre Dame on acetylene led to the development of Neoprene; chromium plating owed its initial commercial impetus to Colin G. Fink of Columbia University; and the work on atomic energy, with its wide range of industrial implications, was initiated in the universities.

Nevertheless there was a tendency, just prior to World War II, to regard the university as a place where "pure" scientists in ivory towers carried on basic research, uncovering knowledge of little immediate practical value. Moreover, it was commonly remarked in industrial research circles that after a student graduated, he had to be practically retrained in the industrial research laboratory.

The change in the status of university work began about 1940, when the government initiated its huge program of defense research, increasing its research expenditures almost tenfold, as shown in the graph on page 189. Naturally, the government laboratories were unable to handle this tremendous load, and recourse was made to the personnel and facilities of industrial and university laboratories.

Fear is frequently expressed that the extensive support of university research by the government will eventually lead to governmental control of scientific thinking. This does not necessarily mean that the government will deliberately prescribe the thinking. The danger is rather that, by defining the areas in which university research will be supported, the government will effectively determine the areas in which it will be concentrated.

Since government interest in research stems largely from defense and

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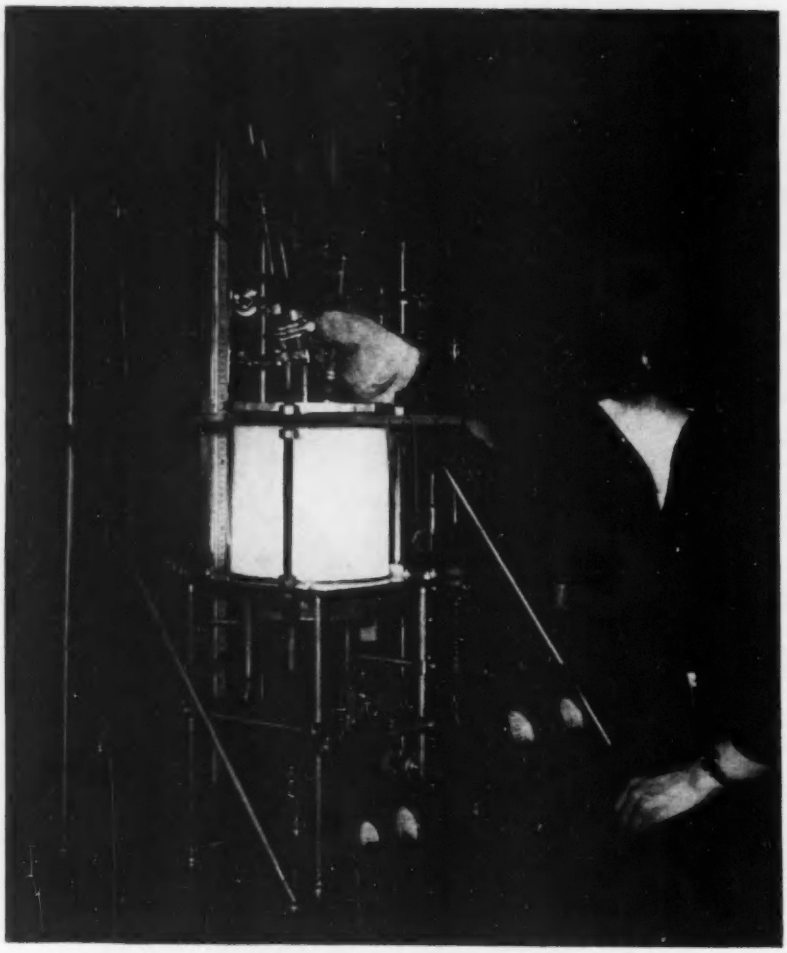


A GLASS-WALLED MULTIPLE HEAD, cold electrode arc melting furnace is used in New York University's Research Div. for investigations in titanium and its alloys.

public welfare motives, it must be expected that the basic research behind such activities will not necessarily be most useful to industry.

Sponsored research has become an important, even an essential, part of the educational system. It has proved that it can multiply the effectiveness of a university in training research personnel and in developing new scientific information. In view of the current shortage of both engineers and research facilities, it is particularly necessary for the universities to make maximum use of their resources to meet the research needs of the nation.

Industry-sponsored research also benefits the university by giving faculty members an opportunity to practice what they teach. It increases the effectiveness of the teacher, who now becomes a practicing scientist or engineer. The old ivory tower concept fades away, and a man comparable to the researcher of industry does the teaching. Instruction becomes both practical and up to date. In this way the university brings to industry the men and facilities to do effective research, while at the same time becoming more useful in its major function of training young research workers.

Who Can Use Facilities

There are in the United States about 200,000 industrial organizations, of which around 3,500 have research laboratories. Naturally, most of these laboratories are in the larger organizations. But all companies, whether large or small, now have access to outside research facilities in the universities, the research institutes, and the commercial laboratories.

In considering who can use university research facilities, it would be logical to assume that the small company, which can not afford a research department, would gain most. But the difficulty here is a matter of economics. If a small company does business amounting to $500,000 a year and puts aside for research 2½ percent of sales (a figure often recommended for research), only $12,500 would be available. Today, this sum would probably not cover even the expense of one competent research scientist.

This would indicate that the expenditure of such funds in an outside research organization, where there is a group of people with diverse technical backgrounds, would be advantageous to the small company, for it would bring a wider range of talents and viewpoints to the solution of its problems than it could obtain internally.

In spite of the obvious advantages in farming out its research, small companies in general do not make as much use of outside research facilities as might be expected. This seems primarily a matter of education and experience. Small companies frequently do not know what to expect from research, nor how to use the results to best advantages. This is by no means entirely the fault of the company. In the past there has been a widespread tendency to be over-optimistic about research results.

A realistic approach to the problem would show the small businessman what he could expect from research in the way of developing new products, processes, and services, and even in helping solve his economic problems; but it would also make him aware of the necessity for integrating research into the company operations. The volume of research should be of a size within the means of the company to exploit. When a new product is developed, manufacturing facilities must be provided to produce it, and the active cooperation of the production and sales departments are required to make it profitable. Research is not an end in itself, but an integral part of the company operation.

If small companies do not use university research facilities as much as might be desirable, large companies with their own large laboratories also do not—at least in normal times. Greatest use of outside research facilities, such as are found in universities, is generally made by companies with moderate-sized research laboratories. Such organizations appreciate the value of research and know how to apply the results to good advantage. They can not economically employ top scientists in all the fields of science in which they are interested; consequently they supplement their own staffs by turning to outside organizations for specialized research. They often find that an outside point of view, even in fields where they are well staffed, is stimulating to their own research employees.

At present, with so much research

directed toward rearmament, both companies with moderate-sized and even those with very large research laboratories are turning to outside sources for help in their research work. This arrangement enables them to carry on the research necessary to maintain their civilian line of goods, while simultaneously fulfilling their obligations in military research without unreasonable increase in staff.

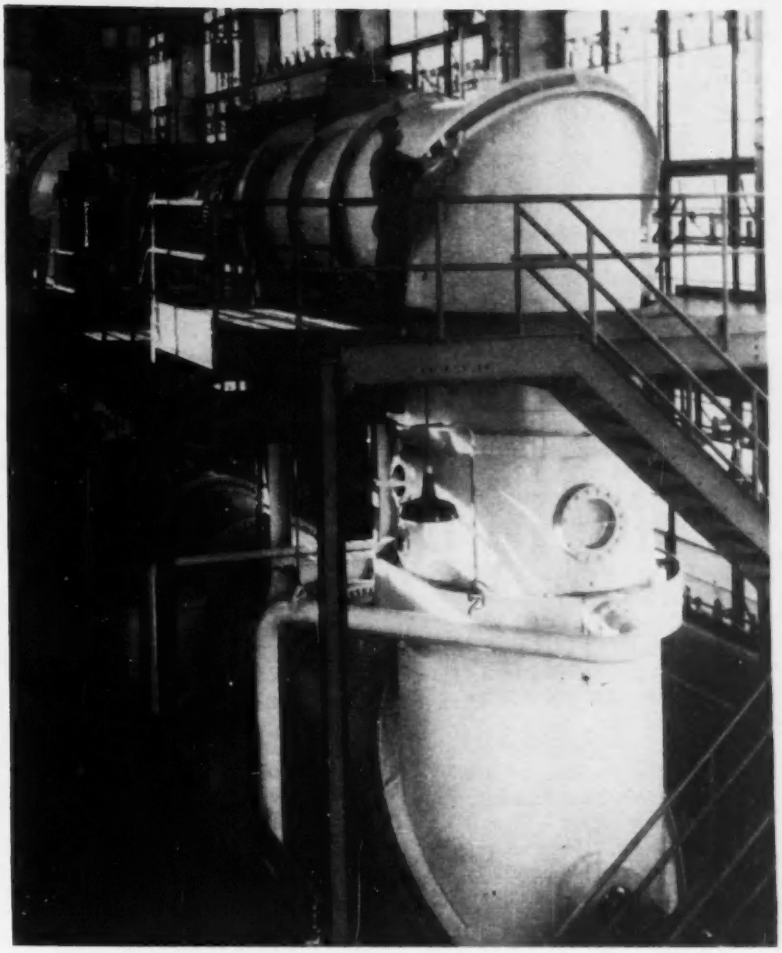
Another organization taking advantage of university research is the industry association. Here companies with common interests group together and submit their problems to an outside agency for solution. While both large and small companies engage in this practice, the operation is particularly valuable when small companies, which otherwise could do little research, are banded together in a common enterprise of sufficient magnitude to be effective. Some technical societies also use university research facilities in much the same manner.

Facilities and Personnel Available

In the past year, a committee of the Engineering College Research Council of the American Society for Engineering College Research Council of the American Society for Engineering Education, under Dean Athelstan Spilhaus of the University of Minnesota, made a study of "University Research Potential." They approached 900 schools, 750 of which replied. Of the 750, 525 submitted definite figures, forming the basis of the report.

Some 25,000 faculty members were studied and 21,000 were judged qualified to perform research. Of these, 13,000 were actually engaged in research, and their efforts were estimated as equal to those 7,000 full time research workers. The faculty members were assisted by some 25,000 graduate students and assistants, whose efforts were considered equivalent to those of more than 12,000 full-time people. This makes a total of 19,000 full-time research workers engaged in university research, about one-half of which is for the defense effort. In addition, there are about 6,000 university people doing medical research.

Compare the above figures with some recent figures for industrial research. In a survey made by the National Research Council, it was shown that in 1950, industry employed about 35,000 engineers and another 35,000 professional people in research work supported by a somewhat larger number of non-professional people, making a total of 165,000 in industrial research. From this it can be seen that university research activity represents the equivalent of a substantial fraction of all industrial research. For purposes of comparison of university with industrial and governmental research, the expenditures of the three since 1941 are listed on page 189.



GARFIELD THOMAS WATER TUNNEL, the world's largest, at Penn State College. Its purpose is the improvement of underwater propulsion, mainly torpedo propellers.

Along with personnel, the ECRC survey referred to also listed special equipment available in universities which, in addition, to the usual research facilities, often have unusual facilities such as wind tunnels, cyclotrons, laboratories for radioactivity studies, mass spectrographs, electron microscopes, electronic computers, towing tanks, and the like.

The availability of university facilities for industrial research varies somewhat from school to school. Some of the small liberal arts colleges do almost no applied research, restricting their efforts to basic research. At the other extreme, some of the state-supported universities are charged in their charters with the duty of carrying on applied research, and even testing, as a part of their regular operations parallel to education. There are other schools that carry on applied research, but only of a type, and to an extent that gives optimum help to their function of education. A few schools have their sponsored research set up in separate and almost independent institutes which have only a slight tie-in with the academic side of the institution.

What To Expect From Such a Program

James F. Bell, formerly President and Chairman of the Board of General Mills, stated the philosohy of a modern corporation in looking into the future:

"One of the greatest dangers that any corporation faces is coming to believe, after a period of well-being or success, in the infallibility of past methods applied to a new and changing future. If we are to enjoy continuing success, our ideas, methods, goods, and services must always be 'better than,' not merely 'as good as.' We cannot afford to go on

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living forever in the shadow of dead men's thoughts."

"The imaginative spirit which puts zest into being is not the exclusive province of youth. So long as the stimulus of iniative and imagination is kept alive, a man, or group of men (and that is all a corporation is) will remain young."

In no small measure, what to expect from an industrially-supported research program in a university depends on what the sponsoring company is looking for. Sometimes industry supports basic research in universities, from which only scientific information is expected or desired. For the most part, however, companies are interested in research that has a scientific value to the company's operations; such as new or improved products, or new processes for making a known product.

The ultimate results of any program will depend in large measure on (a) the skill of the university in handling its research activities, (b) the proficiency of its staff, (c) its patent policy, (d) its policy on publication, and many other factors.

A typical abbreviated statement of policy is that of the Research Division of the College of Engineering, New York University:

"It is the policy of the College of Engineering to undertake, as a rule, only such sponsored projects as (a) seem likely to add to knowledge of fundamental or applied science; (b) are financed by the sponsors on a basis which permits the allocation of part of the gross fee to the Research Fund for the promotion of College-sponsored research; (c) have as an objective the training or further training of one or more research workers; (d) extend over a reasonably long term, preferably a year or more; (e) do not conflict with any other current project or sponsor; (f) are of such a nature that they do not compete with, or can not be successfully undertaken by, a commercial testing laboratory. In periods of national emergency, priority will be given to research projects which are directly concerned with national interests."

The question is frequently raised about the policies of universities with regard to patents that may be developed in the course of their work. The handling of patents varies considerably from university to university. Most of them, by contractual agreement, turn the patent rights over to the sponsor, but there are some that reserve the rights to the patents. Still other universities will not accept research programs from which patents are likely to result. Even so, the patent question is quite an important one to the sponsoring company, for a good patent will bring in considerable revenue from licenses. More often than not, however, the company looks on a patent as protection against having to pay a royalty to someone else.

Sometimes, in a rapidly developing industry, several companies will hold valuable patents which they wish to exploit together. Frequently new companies are formed by the mutually interested companies to develop the new products or processes. It should be noted, however, that the Federal Government does not favor the development of monopolies through patents, and it is usually necessary to license other members of an industry who so desire it.

Another point for consideration is the university's policy on the publication of research results. Most universities do research with a view to adding to the general store of information. While the universities are eager to publish research results, most of them are willing to delay publication sufficiently to allow patent matters to be handled, and to this end, they usually agree to publish only with the approval of the sponsor.

Not all publication problems, however, arise from the university's desire to publish. Frequently it is the sponsor who wishes to publicize the results of research, thereby taking advantage of the prestige associated with the university's name. Most universities prefer not to have their names used in advertising or publicity connected with commercial products. Consequently, they allow use of their names in this way where the text is first submitted to them for approval.

It should be recognized that an individual research venture is a speculation. Leo Baekeland, who had to his credit two successes—Velox photographic paper and Bakelite—was once asked how many unsuccessful researches he had carried out for every one that succeeded. He claimed that one try in fifty was successful. Others say that perhaps one in ten should succeed.

How to Set Up the Program

Recommending ways of setting up a research program in a university is a risky thing to do. There are unquestionably more wrong ways than right ones. Nevertheless, certain general principles that may be laid down will be of some help.

Perhaps the most important step, from the company point of view, is making a top official responsible for planning and setting up the program, to ensure proper integration of research results with company operations. In a large company, of course, this authority may be delegated to some suitable person down the line; but the chain of authority should be such that the work eventually goes through the hands of a person sufficiently high to tie it in with other operations of the company.

The next problem is the selection of the institution which will do the research. Here the primary consideration is the availability of qualified scientists to carry out the work. Gifted men are the keystone of the research structure. Success in research is much like the tendency toward accidents among automobile drivers, where 15 percent of the drivers cause 85 percent of the accidents. Much the same situation exists among research workers; a limited number of scientists seem to be responsible for the lion's share of the results. That being the case, it is important to see that the best available researchers are put on the job.

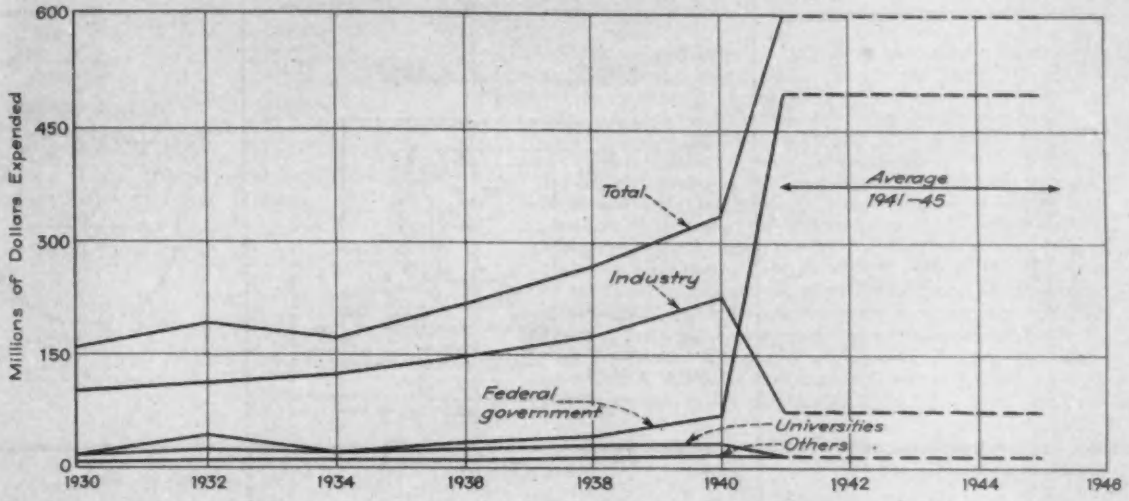
However, it is not enough just to have competent scientists. They should be amply supported by library facilities, technicians, stenographic help, and the like, so that they can concentrate their energies on the scientific phase of the problem. And to round this picture out, there should be good business management and policies behind the research operation, so that the work of the scientists may be carried out with maximum efficiency.

Assuming that the organization is satisfactory, the equipment situation should then be examined. In some cases, equipment is the controlling factor in placing research. Generally speaking, however, universities that have been operating in a given field for any great length of time are well situated in this respect. Indeed, they frequently have special facilities for work on nuclear energy, aerodynamics, or medicine, that are costly to set up, and could hardly be justified by organizations other than the government or the largest industrial corporations.

Another important point for consideration is the geographical location of the university with respect to the sponsoring agency. When research for a given organization is carried on by an outside agency, there is always a problem of communication of ideas between the two groups. It is generally desirable to have frequent meetings between the sponsor and the university —say at least once a month—to discuss the progress of the work, and later its application.

In placing research work with a

Comparison of National Research and Development Expenditures 1930-1945 (Excluding Atomic Energy)



Estimated Research and Development Expenditures in U.S. 1941-1952 (In Millions of Dollars)

Year	Total	Source of Funds		Use of Funds by Type of Institution		
		Other	Federal	Indust.	Univ.	Federal
1941	800	560	240	520	80	200
1942	930	590	340	600	90	240
1943	1,050	420	630	650	100	300
1944	1,200	430	770	700	110	390
1945	1,300	420	880	750	120	430
1946	1,490	830	660	890	130	470
1947	1,810	1,020	790	1,120	170	520
1948	2,060	1,140	920	1,290	200	570
1949	2,080	1,030	1,050	1,310	220	550
1950	2,240	1,200	1,040	1,430	240	570
1951	2,590	1,280	1,310	1,630	260	700
1952	2,930	1,290	1,640	1,820	280	830

Source: Research and Development Board, Department of Defense

university, the prospective sponsor should avoid putting too much weight on cost. Selection of a research organization should be handled in much the same way as the selection of a doctor for treatment of a serious disease. A highly qualified specialist with the best of equipment, conveniently located, is the best bargain in the long run. However, this does not necessarily mean the lowest cost. All too frequently, low costs for research, whenever done, result from use of inadequate personnel or insufficient equipment, and in the end only lead to grief.

The nature and extent of research projects varies greatly. Many universities avoid accepting projects which involve less than the equivalent of the full-time efforts of one man for one year. Such a minimum program may cost from $10,000 to $20,000, depending on the personnel and other requirements.

As for the upper limits, war research demonstrated that the universities can, if they wish, handle almost any size project that industry cares to refer to them. It becomes a question, therefore, of finding what scale of approach best fits the needs of the sponsor.

Research is not just an isolated scientific operation. If it is to benefit the sponsoring agency, it must be an integrated part of company operations. Only under this condition will it be completely satisfactory both to the company and to the university.

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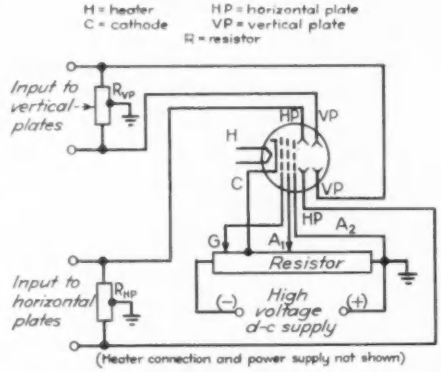
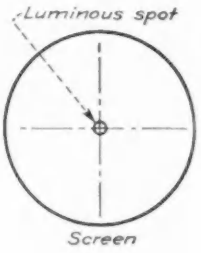
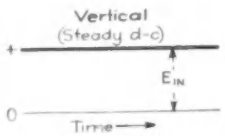
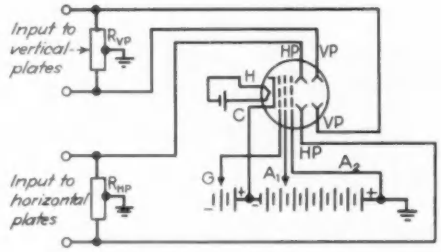
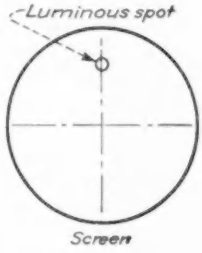
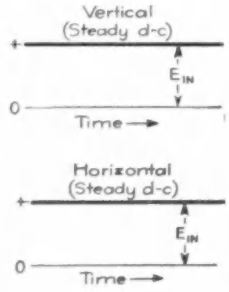
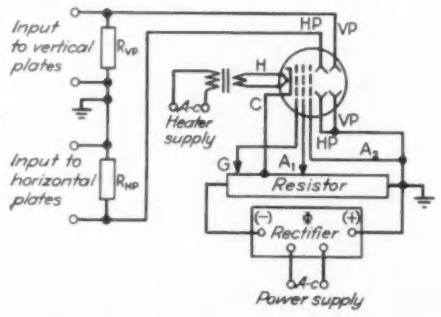
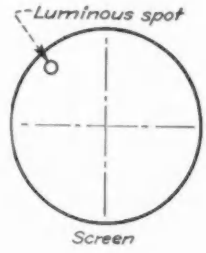
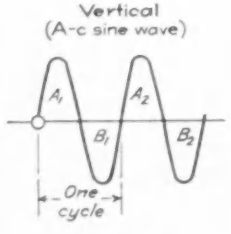
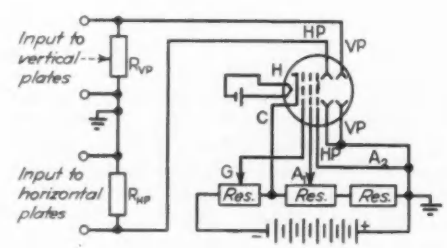
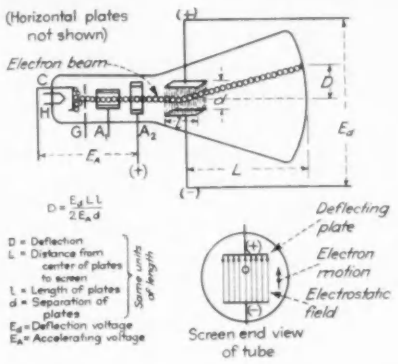
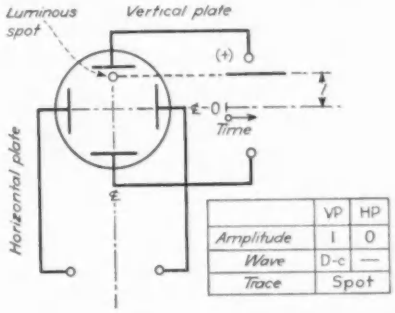
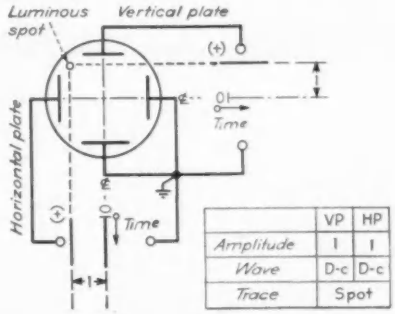
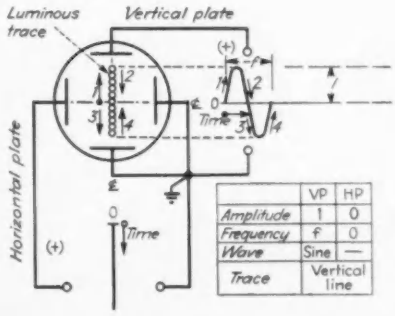
Type	Input Voltage	Circuit Sketch	Output Trace
Basic Circuit for Electro-Statically Deflected Cathode-Ray Tube	Vertical (No Input) Horizontal (No Input)	H = heater, C = cathode, HP = horizontal plate, VP = vertical plate, R = resistor  (Heater connection and power supply not shown)	
Voltmeter			
D-C Voltage Polarity and Magnitude Comparator			
Cathode-Ray Tube With ■ Sinusoidal Vertical Sweep			

for Voltage Wave Form Analysis

RALPH B. IMMEL
Westinghouse Electric Corporation

Operation	Remarks
	Electrons emitted from the cathode are focused by the first and second accelerating anodes into a concentrated beam. The electrostatic field produced by the two anodes is analogous to an optical lens system for converging light rays as it makes the electron paths converge to a point on the fluorescent screen. A narrow beam of rapidly moving electrons is known as a cathode ray. The electron beam can be deflected vertically or horizontally by electrostatic fields emanating from the deflecting plates. The electron beam deflection is at right angles to the plane of the deflection plates and is attracted to the positive plate and repelled by the negative. The cathode-ray tube is a tool that can be successfully used in the measurement of voltage, current, power, or frequency; determination of amplitude, phase, and frequency modulation patterns; amplifier and transformer response to a square-wave voltage wave; determination of vacuum tube characteristics; checking the response, alignment, coupling, and band of frequency response of tuned resonant circuits; and innumerable other applications.
	The cathode-ray tube may be used as a voltmeter in a circuit similar to the one shown if the tube is calibrated for electron beam deflection vs the potential applied to the deflecting plates. The deflection may be measured on a linear scale as the deflection is directly proportional to the deflection voltage E_d. Deflection sensitivity is the ratio of the movement of the luminous spot on the screen to a unit voltage applied to the deflecting plates. Sensitivity is usually expressed in millimeters per volt. The potential of the second anode affects the sensitivity. The cathode-ray tube is more sensitive for low than for high anode potentials because a less intense electrostatic field is required for a given deflection of an electron beam with a low velocity.
	A d-c potential applied to both plates deflects the beam both vertically and horizontally. The kinetic energy released by the impact of the electrons when they bombard the screen produces fluorescence or the emission of light. The continued emission of light from the screen after the bombardment has ceased is known as phosphorescence and depends upon the screen coating, velocity and concentration of the electron beam. The color of the light depends upon the phosphor coating. Continued bombardment upon one spot of the screen reduces the sensitivity of the coating. If the focused electron beam is allowed to remain in one spot too long, it may not only destroy the phosphor coating, but may also melt a hole in the end of the tube.
	The luminous spot moves up and down in simple harmonic motion when a sine wave of voltage is applied to vertical plates. The first anode is usually designated as the focusing anode because the potential applied to it determines the focus or sharpness of the electron beam convergence at the screen. The second anode is usually operated at a fixed potential while provision is made to permit adjustment of the first anode potential, the luminous spot can be adjusted or focused to a very distinct spot on the screen.

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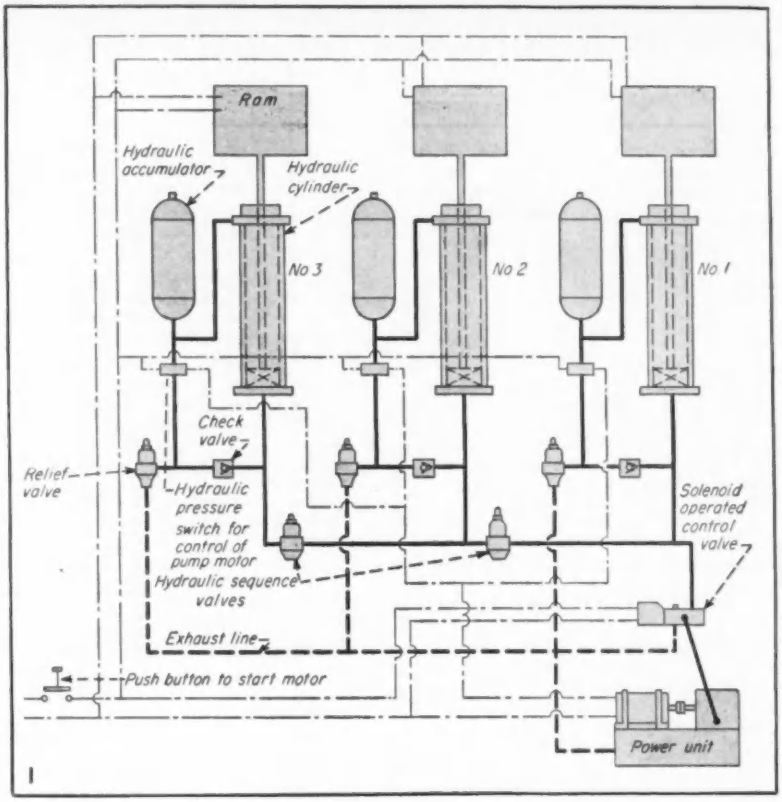
Improve Circuit Performance

ACCUMULATORS are pressure storage chambers in which the noncompressible hydraulic fluid is stored under pressure from an external source. They are used for an emergency source of power, for holding pressures over long periods, for volume compensation, for fluid dispensing, for increasing circuit component speed, and for many other applications.

There are three general classifications of accumulators: (1) dead weight; (2) spring loaded: and (3) air operated, with the air operated type being the most popular.

The dead weight accumulator consists of a weight acting down on a hydraulic piston, with the weight of the mass supplying the stored energy. The advantage of this type is that accumulator pressure is constant for the complete stroke. A disadvantage is that it is bulky and very heavy. It is usually built to order on the job, and because of its high cost one installation supplies accumulator action for several machines.

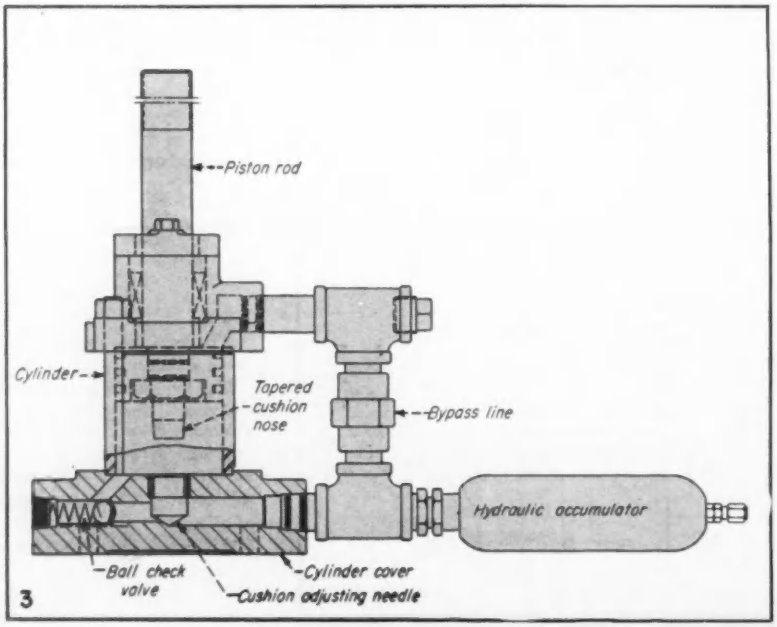
Spring loaded accumulators use one large spring or a group of smaller springs acting against a hydraulic piston, with the energy stored in the compressed springs. This type may use limit switch pump control, or may use a pressure switch set for a predetermined pressure differential. The main disadvantage is that there is drop in pressure during the stroke.

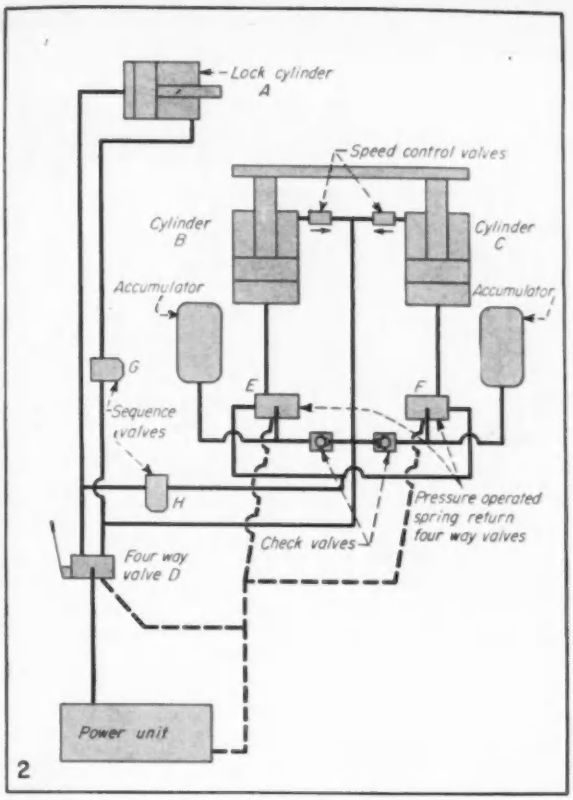


Air operated accumulators store energy because of the compressibility of air. They may be divided into two groups, the piston type and the bag type. The piston type is usually designed with the air piston larger than the hydraulic piston so that the hydraulic pressure may be several times the required air pressure.

The bag type accumulator is the most common and versatile. It consists of a steel shell enclosing a synthetic bag. The bag is precharged with air to the required pressure, and the hydraulic fluid occupies the space between the shell and the bag.

The following circuits show typical hydraulic systems in which the various types of accumulators have been used to improve performance.





1. Fail-Safe Circuit. This system makes use of three accumulators as sources of emergency hydraulic power. It is desired for safety reasons to retract all rams should something happen to interrupt the normal supply of oil pressure to the cylinders.

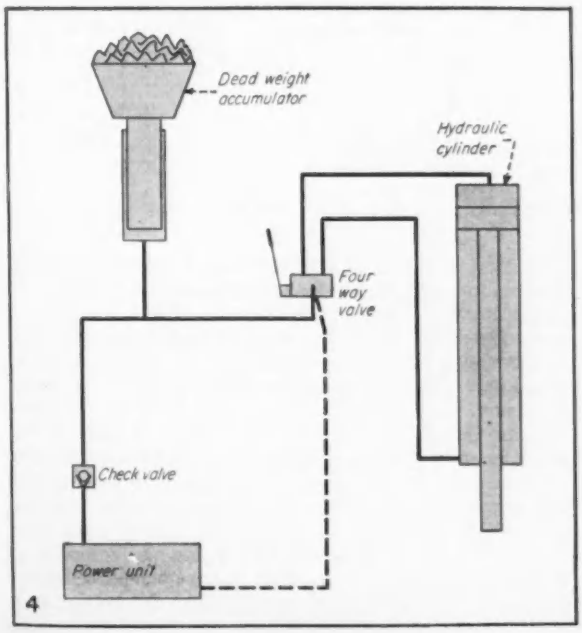
In the circuit sketch, power lines are shown carrying electrical energy to the rams. For the purpose of this discussion, it can be assumed that the rams act as carriages for electric tools equipped with rotating cutters or blades. If power to the hydraulic pump fails, either because of a fault in operation or because the pushbutton is released, the oil stored in the accumulator tanks withdraws these tools to a guarded position.

When the pushbutton is held closed, the electrical circuits to the pump motor, ram tools, and the spring-return solenoid valve are completed. The first cylinder advances to the end of its stroke. Then, the sequence valve opens, allowing oil to flow to the second cylinder. This action is repeated until all pistons are in the extended position. The power unit continues to function, pumping up the three accumulators. As each accumulator reaches full charged conditions, its associated pressure switch opens. When all three pressure switches have been actuated, the power unit is deenergized.

When the pushbutton is released, or in the event of a power failure, the solenoid operated control valve shifts. The blind ends of the cylinders are then open to exhaust and the oil pressure in the accumulators causes pistons to retract.

While this system only includes three sets of cylinders and accessory components, the same circuit arrangement can be used for as many sets as desired.

With Hydraulic Accumulators



H. L. STEWART
Logansport Machine Company, Inc.

2. Synchronizing Piston Movement. Accumulators can be used to synchronize the piston movement of short stroke cylinders. In this circuit the accumulators synchronize the outward travel of the two cylinders *B* and *C*, while additional circuit components control the optration of the locking cylinder, *A*.

The four way valve *D* controls the direction of motion of the three cylinders. With its operating lever to the left, oil flows to the rod end of cylinders *B* and *C* and at the same time charges the two accumulators. When the pistons are retracted and the accumulators charged, sequence valve *G* opens, supplying oil to the rod end of the locking cylinder *A*. With the operating lever of valve *D* to the right, oil flows to the blind end of cylinder *A* and the piston moves out. When it reaches its outermost position, sequence valve *H* opens and pressure operated valves *E* and *F* are actuated to open, allowing oil from the accumulators to enter the blind end of cylinders *B* and *C*. These pistons move out uniformly under accumulator pressure. The speed of movement of the cylinders *B* and *C* is controlled by the settings of the speed control valves. At the end of this stroke the cycle is complete.

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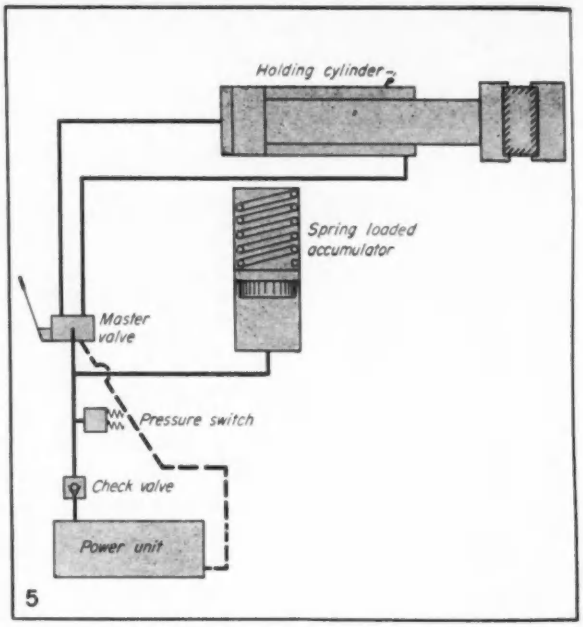
3. Fluid Makeup. In closed hydraulic systems, it is sometimes necessary to provide a source of oil to make up the difference in fluid volumes between the rod end and the blind end of a hydraulic cylinder. In such cases, the accumulator may provide a satisfactory solution.

A possible application is shown in the sketch. When the rod of the cylinder is moved in by an external force, oil flows through the bypass line to the rod end of the cylinder. Since the volume of oil in the blind end of the cylinder is greater than that in the rod end, when the rod is being retracted there is an excess of oil that must be stored somewhere. The accumulator is provided for this purpose.

As the piston is forced in, oil gradually fills the accumulator. The cushion adjusting needle acts as a flow control valve to restrict piston speed and thereby prevent shock at the end of the strike.

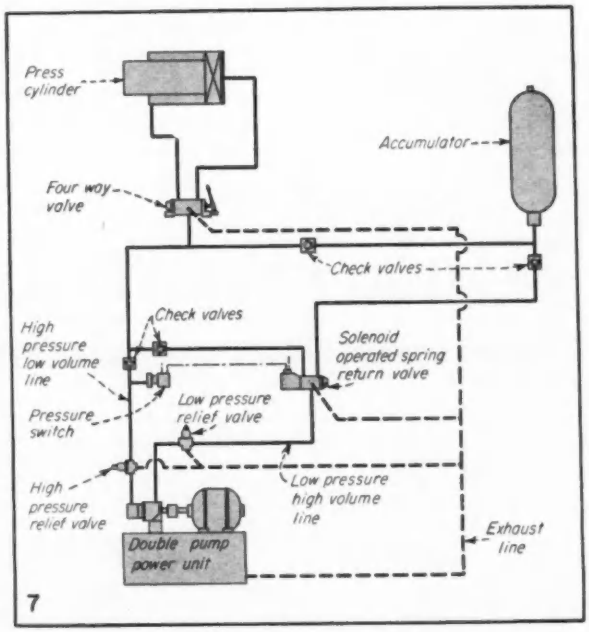
When the piston rod is extended—again by an outside source—oil must be added to make up for the greater space in the blind end of the cylinder. The needed volume of oil is supplied by the accumulator, which dumps its charge back into the closed system.



5

4. Hydraulic Shock Suppression. Hydraulic shock or water hammer is usually caused by the sudden stoppage or deceleration of oil in a line. This effect is particularly noticeable when high volume, high pressure flows are suddenly throttled, and can damage sensitive equipment or under severe conditions rupture a line. By installing an accumulator just ahead of the shut-off point, the shock will be suppressed.

In this application, the abrupt shutting of the four way valve and the sudden deceleration of the rapidly moving oil will cause a series of shock waves which are absorbed by the dead weight accumulator, thus protecting the line and any attached instrumentation.



7

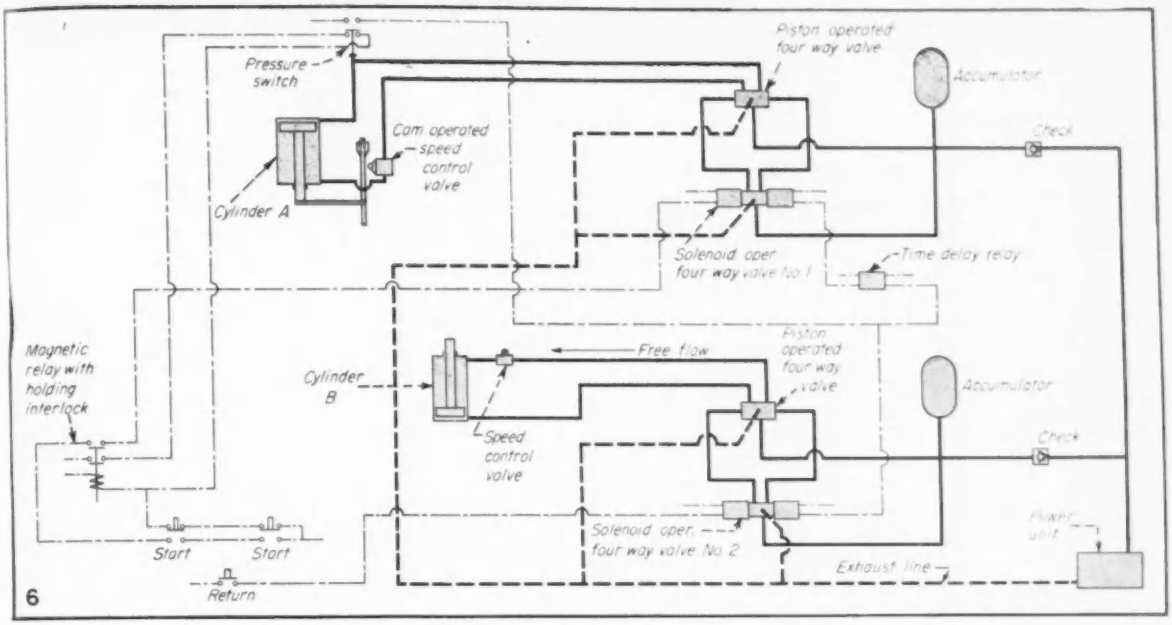
5. Leakage Compensation. Intermittent pump operation is satisfactory when there is an accumulator in the circuit to compensate for leakage. The pressure switch is set to operate between a fixed differential depending on the size and stroke of the spring loaded accumulator. With the system originally at maximum pressure, the accumulator makes up system leakage until the pressure drops to the allowable minimum. The pressure switch closes the circuit to the pump motor which operates until the oil pressure reaches the maximum operating pressure. The pressure switch then opens, stopping the pump.

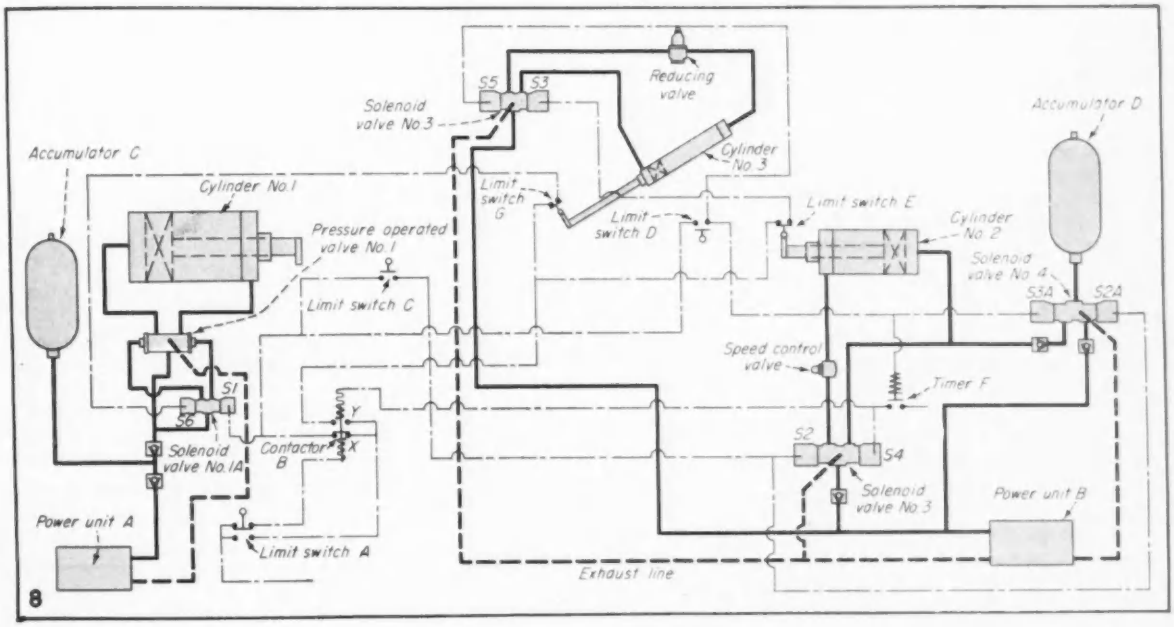
Since oil is virtually incompressible; without the accumulator the pump would be continuously cycling to compensate for system leakage. If desired the accumulator can also be selected so that it is large enough to supply oil for some circuit component operation.

Some accumulators of the spring loaded type are built with external trip rods which actuate a limit switch to turn on the power unit when minimum pressure is reached, and turn it off when the system is up to maximum pressure.

6. Intermittent Duty Cycle. In circuits where there is a long interval between operations, accumulators can be used as a secondary power source, with a small pumping unit as the primary source. In this casting press circuit the accumulators supply the high quality of oil required by cylinders *A* and *B*, while the small power unit charges the accumulators during standby periods.

When the pump has operated long enough to charge the accumulators, the cycle can be initialed by pressing both start buttons. The magnetic relay is locked in through the bottom contacts of the pressure switch. When the circuit is completed through the start buttons, No. 1 solenoid valve is energized and causes its piston operated valve to move in the direction to supply-oil to the top port of cylinder *A*. The piston moves downward at a constant speed until the cam operated speed control valve is actuated, reducing the speed of piston travel. When the end of the stroke is reached, the oil pressure above the piston increases, since there is no longer any line drop, and the pressure switch operates. This energizes the time relay and the right hand solenoid of valve No. 2, at the same time deenergizing the start button circuit and the solenoid of valve No. 1. Valve No. 2 and its piston operated valve are actuated in the direction to supply oil to the bottom port of cylinder *B*. When the time delay relay closes it energizes





solenoid valve No. 1 to retract cylinder *A*. Cylinder *B* may be retracted by pushing the return button and the cycle is complete.

The accumulators are selected to supply sufficient oil for at least one cycle, and are recharged between cycles. Without them a much larger pumping unit would be required.

7. High Speed Operation in Two Pressure System. In applications such as this hydraulic press circuit, an accumulator can be used to give increased capacity for greater piston speed during nonworking portions of the cycle. This reduces total cycle time.

The system is equipped with a high volume, low pressure pump and a low volume, high pressure pump. When the handle of the four way valve is shifted to advance the press cylinder, both pump deliveries as well as the accumulator discharge act on the cylinder piston and move it rapidly. When the ram meets sufficient resistance the system pressure builds up and actuates the pressure switch. This in turn energizes the solenoid operated valve so that the delivery from the large volume pump is directed to the accumulator for recharging. The small volume pump supplies high pressure oil to the cylinder for the pressing operation.

When the four way valve is shifted for the return stroke of the cylinder, again both pump deliveries and accumulator discharge are available. Also at this end of the stroke the small volume pump holds the cylinder while the large volume pump recharges the accumulator. The two relief valves limit system pressures to the required high and low pressures while the cylinder is at either end of the stroke.

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By using accumulators in this manner, cycle time is reduced since circuit components operate at high speeds during the nonworking, low power portions of the cycle. Similar results may be obtained with a large high volume pump, but at much greater cost.

8. High Speed Operation in Single Pressure System. This electro-hydraulic control and power system for an automatic die casting machine employs two accumulators to increase the rate of piston travel in cylinders 1 and 2, over that which could be obtained with the power units alone. This circuit differs from the previous one in that only one pump is used in each of the individual hydraulic networks instead of separate moving and holding pumps.

Thus the increase in speed of operation during the nonworking portions of the cycle must come from the accumulators, since there is no auxiliary pump.

With cylinders Nos. 1 and 2 in the retracted position and cylinder No. 3 in the out position, the cycle is initiated by closing the gate which in turn actuates limit switch *A*. Contactor *B* is in position *X*. Solenoid *S*1 of valve No. 1*A* is energized, directing pilot pressure to valve No. 1 which operates to admit oil to the blind end of cylinder No. 1. The piston is driven outward at high speed by the discharge of accumulator *C* and power unit *A*. When the piston reaches the end of its stroke, limit switch C is actuated. The check valve in the line to valve No. 1 prevents the piston from retracting and accumulator *C* recharges.

When limit switch *C* closes it energizes solenoid *S*2 of valve No. 2 and solenoid *S*2*A* of valve No. 4. Accumulator flow from the right hand port of valve No. 4 and the supply from pump *B* enter the supply port of valve No. 2 and in turn are directed to the blind end of cylinder No. 2, driving the piston out at a rate determined by the speed control valve in the rod end line. At the end of the outstroke of cylinder No. 2 limit switch *D* is closed energizing solenoid *S*3*A* of valve No. 4, solenoid *S*5 of valve No. 3, and timer *F*. The accumulator recharges through the left hand port of valve No. 4 and the check valve in the supply line to valve No. 2 prevents the piston of cylinder No. 2 from retracting during further cycle operations.

When solenoid *S*5 of valve No. 3 is energized, oil is admitted to the rod end of cylinder No. 3 and its piston retracts at a rate dependent on the capacity of power unit *B*. After a predetermined time interval the timer *F* closes, energizing solenoid *S*4 of valve No. 2 and cylinder No. 2 retracts. The timer contract also energizes the *Y* coil of contractor *B* which closes the circuit to limit switches *E* and *G*. Limit switch *E* is actuated when cylinder No. 2 is fully retracted and energizes solenoid *S*5 of valve No. 3 causing the piston of cylinder No. 3 to move outward. At the end of this stroke, limit switch *G* closes, energizing solenoid *S*6 of valve No. 1*A* and causing valve No. 1 to operate to retract cylinder No. 1. When the gate is opened limit switch *A* is released and contactor *B* moves to the *X* position completing the cycle.

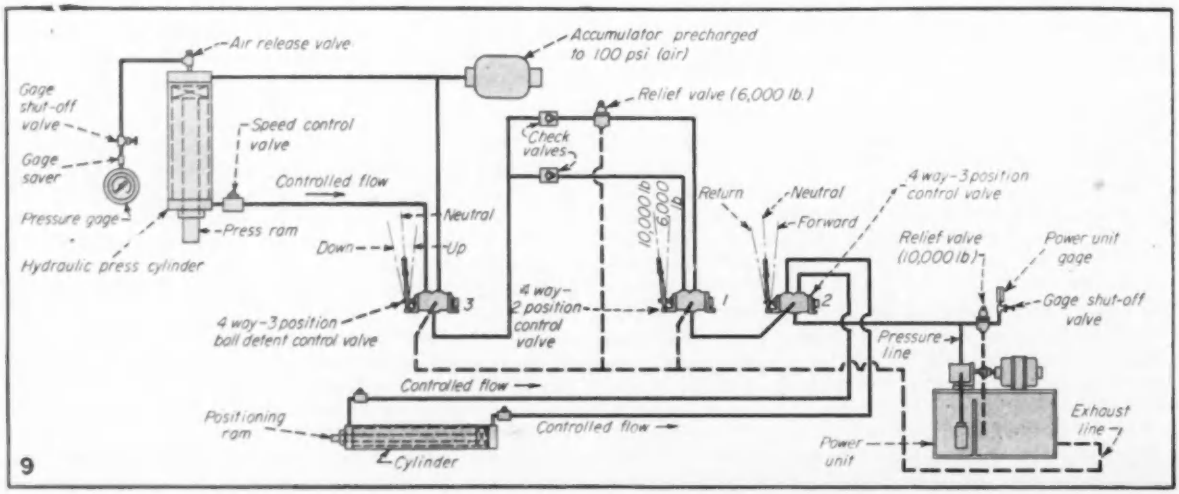
9. Holding Pressure. An accumulator can be used to maintain high working pressures on cylinders and other circuit elements for long periods of time. With this scheme, the master valve can be shifted to neutral once system pressure is built up. This allows the pump pressure to drop almost to zero, reducing the wear on motor and pump and minimizing the possibility of overheating the oil.

In the circuit shown, an accumulator is put to such usage. At the start, the hand lever of control valve No. 1 is moved to the 10,000 lb total ram force position. Then, when the lever of ram operating valve No. 3 is pulled forward, the press ram descends to exert full pressure on the work. The hand lever is now placed in the neutral position, blocking the cylinder ports and opening the pump unit to exhaust. Since the cylinder ports are completely blocked off from both pump and exhaust, the pressure stored in the accumulator maintains the force of the ram against the work.

After the pressing operation has been completed, the lever of valve No. 3 is pushed into reverse. This causes the ram to move upwards. Of course, the ram can be stopped at any point in ascent or descent by shifting the valve to the neutral position.

This circuit makes available two working pressures. The 10,000 lb rating is determined by a pressure relief valve located near the power unit. A second total ram force of 6,000 lb is regulated by a relief valve in a bypass line installed after valve No. 1. The desired pressing force is selected by means of the latter valve.

For operation of the work positioning ram, the handle of valve No. 2 is pulled and held. When the ram has traveled to the proper position under the press ram, the valve handle is released. When this valve, too, is in the neutral position, all cylinder ports are blocked and the pump is bypassed through valve No. 1. From this valve, the oil supply is shunted through the ram operating valve back to the tank.



The Reader AUDITED PAID CIRCULATION ABC *His Mark*

THE ABC SYMBOL which is printed at the head of this page is, in a very real sense, *your* brand on this magazine. Those letters stand for Audit Bureau of Circulations. The symbol indicates that the magazine is a member and supporter of that Bureau.

To the advertiser who contemplates using the magazine as an advertising medium, this symbol has a well-recognized significance. It tells him that the circulation records and practices of the magazine are wide open to the auditors of the Bureau, who check the publisher's claims and make public the precise terms and conditions under which subscriptions are obtained. And it assures him that the magazine stays in business by virtue of a demonstrated demand from its readers as shown by their paid subscriptions or newsstand purchases.

BUT HERE we are concerned only with the significance of ABC to you as a reader. For when the advertisers, the advertising agencies, and the publishers founded the Bureau nearly forty years ago to help establish honest circulation figures, they unwittingly set up a cooperative institution that has become a major safeguard for the interests of the reading public.

That is because membership in ABC constitutes one of the strongest guarantees that any publication can offer of its primary devotion to the interests of its readers. And by making that guarantee possible, ABC becomes a major safeguard of the freedom of the press, an objective of exceptional importance in these days when the public is flooded with propaganda from so many sources.

THE SUREST MEANS by which to preserve a free press is to keep it directly answerable to the reading public it would serve. It follows, then, that the survival of a truly free press must depend on its acceptance by that public; and that means in turn that the people must have in their hands some adequate means for holding the publishers responsible to them.

No one has yet devised any means to that end more simple, more direct or more practical than the paid subscription or newsstand purchase price. The right to purchase or refrain from purchasing a publication gives to the readers and to no one else the power to pass judgment on whether that publication should continue to serve the reading public.

TO SUPERVISE this vital process, to check and certify the integrity of the publication's circulation methods and claims, requires a strict and continuing audit of each publication's success in meeting this test of its public acceptance. To that essential function the ABC has contributed mightily by the conscientious performance of its mission. And that is why we are able to have a press supported, for the most part, by advertising revenues, but not controlled as to its circulation or content by any influence other than its readers.

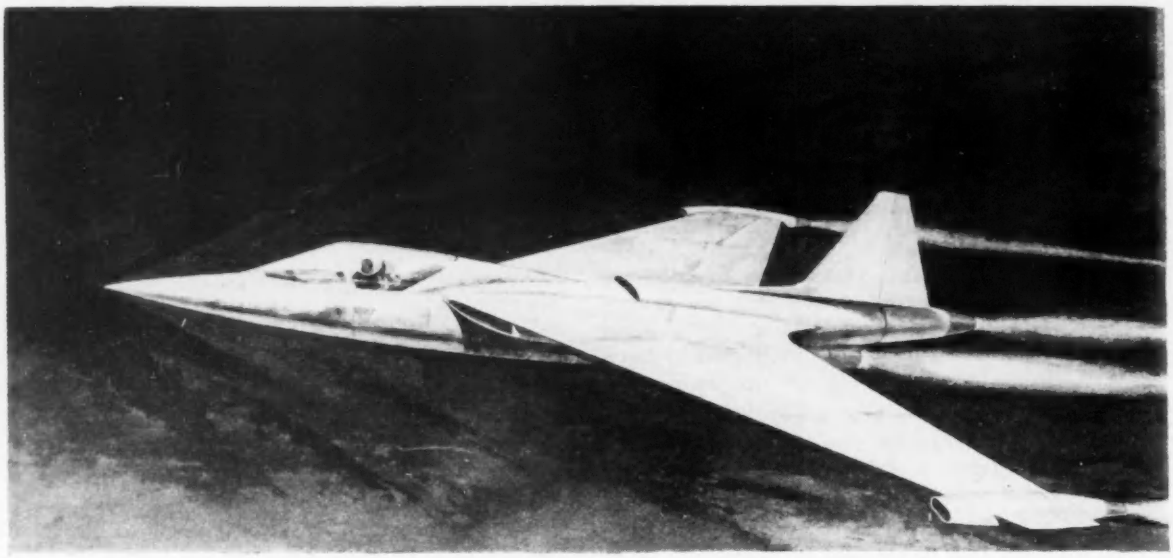
When an advertiser consults the ABC statement of a publication to ascertain the amount, the quality and the trend of its circulation, he does so in the legitimate pursuit of his own interest. But at the same time, inevitably, he is helping the ABC to keep the press responsible and responsive to the reading public. For, in effect, he is asking the publication to demonstrate through its circulation figures that it owes its standing to a voluntary demand by its readers.

SO THE Audit Bureau of Circulations, by auditing and certifying paid circulations, has come to perform a vital service to the readers of this magazine and of every other member publication. And in performing that service, it helps to maintain in our country a press that is answerable to the reading public and to it alone. So long as the practices and principles for which ABC stands continue to prevail in American publishing, we shall find in it a sure support for a truly free press, responsible only to the public it serves.

McGraw-Hill Publishing Company

CIRCULATION AUDITED BY ABC

TECHNICAL NEWS



SUPER SPEED AIRPLANE may have glass-plastic wings, ailerons, stabilizers and fuselage. It will be fastened with glass-plastic rivets and will have titanium load members according to Northrop Aircraft materials specialists who are studying the problem.

New Materials Needed for Super-Speed Airplanes

IF AIRCRAFT DESIGNERS are to continue the trend to develop faster airplanes, they need help from material specialists who can answer these questions: Of what materials can super-speed planes be made? How are they to be fastened together? How can such aircraft negotiate the "heat barrier" which lowers the mechanical properties of present aluminum and magnesium alloys at extreme velocities? To fly at speeds two or three times the speed of sound, an airplane must be able to stand the ram-compression temperature rise on the skin surfaces over which the air passes.

Thomas B. Piper, director of materials and process engineering at Northrop Aviation, claims that glass plastic laminates appear to offer the best answer to good service at high speeds. Piper visualizes aircraft of the future made of woven glass fabric laminated with temperature resistant materials such as phenolic resins or silicones.

His reasoning: A glass reinforced plastic structure would have a favorable strength-weight ratio and would maintain a high percentage of its strength at temperatures in the vicinity of 500 F. The molded material would have a lower coefficient of expansion than a metal structure so that localized dimensional changes produced by differential exposure to heat would be less severe than in metal aircraft. The low heat transfer properties of the molded laminate and the fact that it is integrated with like materials possessing uniform coefficients of expansion should reduce thermal structural warpages and eliminate aerolastic variations that could damage the airplane and establish critical control problems.

As a process engineer, Piper sees other advantages to reinforced plastic. Simplified tooling would reduce production costs since it is possible that a complete airframe could be molded from plastics in four or five basic molds with only a handful of skilled workers required for the operation.

British airframe manufacturers apparently agree with Piper on glass reinforced plastics. They have fabricated a set of glass-plastic wings which will be flight tested early next year.

Next to glass-plastic, the Northrop engineer feels that titanium is the most promising material for the aviation industry.

He said, "Despite the disappointment for those who were too quick to proclaim titanium the "wonder metal," it is now winning sound recognition as a material for load-carrying members because of its strength-weight ratio and its ability to withstand corrosive attack at high temperatures."

While research programs aimed at developing better phenolic resins and lowering the cost of titanium make the super speed airplane appear close to completion, the problem of how to fasten it together has not been resolved.

Northrop's work with glass rivets in plastic structures has been disappointing. Fastening experts feel that the answer may be either: glass roving with unidirectional fibers impregnated with silicones or phenolics, or a titanium removable blind fastener.

Another materials problem that has to be solved is in the field of lubrication. Piper thinks that the solution may be a metallic-dry-powder or dry film type such as molybdenum disulfide with or without a carrier. He feels that wet lubricants developed to give service in the range from 350 to 700 F will probably be unsatisfactory for extreme low-temperature operation; they may also exhibit rather poor lubricity or have undesirable toxic or corrosive properties.

Other material substitutions that will be required for the super-speed airplane include: changing the methacrylate plastic cockpit canopy to something like silicate glass; new heat-resisting rubber-like materials for

sealing applications; new surface finishes; and new fuels with vapor pressure low enough so that they won't boil at the temperatures produced in the fuel by the ram temperature increase.

Most encouraging is the fact that none of these new materials appears to be impossible. Piper admits that it will take many hours of research to accomplish, but he feels that every industry will benefit along with the aircraft industry.

Cool Weather Chills Flying Saucer Reports

WASHINGTON—The passing of summer's hot humid weather put a temporary end to the flood of flying saucer reports and gave added impetus to the belief that the unknown phenomena sighted in many parts of the United States are the result of temperature inversion in the air.

Harvard astronomer Dr. H. D. Menzel suggests that the flying lights are caused by the total reflection of ordinary light sources such as headlights. He explains that normally the temperature of the air declines about 3.5 F per thousand feet of altitude. But under certain conditions, layers of air at higher temperatures get sandwiched into the cold air, causing what is known as temperature inversion. Because of the difference in density, the inversion layer has a different index of refraction than the cooler air, and lights from the ground are totally reflected back down by the layer. As a result, observers away from the source see the lights apparently in the sky; and since both the layer and the source may be moving, the flying saucers perform incredible movements.

Menzel has built a laboratory apparatus in which he can set up an inversion layer of air and make phenomena similar to flying saucers.

Ionization Theory

Another explanation was propounded by a scientist at the Fort Belvoir Engineer Research and Development Center. He reported that when ionized balls of air are injected into rarefied air, the balls glow. In addition, they move about in an eccentric manner at high speed. Again, he was able to build a laboratory apparatus that would produce this phenomenon.

It's quite likely that both of these theories are required to explain all the flying saucers that have been reported by credible observers. Most scientists who have studied the problem feel that the blundering manner in which the Air Force attempted to pass off the reports as imagination only added to the confusion and convinced the public that the Air Force was trying to cover something up.

When August dogdays hit Washington, a flood of visual and radar flying saucer reports forced the Air Force to tell all they know about the subject.

The solid official viewpoint was expressed by Major General John A. Samford, Chief of Air Force Intelligence.

General Samford said, "We have received many reports of incredible things from credible sources. But there is nothing to indicate that the things seen or reported to have been seen in the skies are vehicles, material things, missiles, or anything elese that might comprise a threat to this country." The chief of intelligence added that about 20 percent of the reports cannot be explained. The remainder can be associated with jet planes, balloons, or some other object.

Now the Air Force admits that the unaccounted-for 20 percent of the flying saucers are not imagination; they claim they are optical, climatic, or atmospheric phenomena.

Old Stuff

According to saucer experts, the non-existent flying objects are not new. They have been reported since biblical times. There was a similar rash of reports in this country about 1846 and nothing came of these flying mysteries at that time. The Air Force has been investigating the current version since 1947. To date, nothing tangible has come from them, since nothing has ever been recovered from a crash.

Recent radar sighting of flying saucers adds little information to that already gathered, because radar experts are used to their equipment picking up ghosts. Best example: During World War II a Navy task force off the coast of Alaska fired over 1,000 rounds of ammunition at an enemy picked up on radar. When the enemy didn't fire back, the Navy discovered their radar had picked up reflections from fog banks. Some specialists feel that radar waves can be reflected by the inversion layer just as light waves are; this would produce pips on radar scopes where no pips should be.

However, the flying saucer mystery has not been dispelled to the satisfaction of everybody. People still hold on to their pet theories, such as:

1. One investigator, a chemical engineer by profession and a saucer expert by avocation, claims that the saucers are actually guided missiles that belong to the Navy. His reasoning: most reports come from areas close to naval installations and the saucers travel courses of established radio lanes where radio beams would be helpful to Naval Scientists in flight control.

Visitors from Space?

2. Another expert figures that the saucers are from outer space, visitors from another planet. In his opinion, they are guided missiles controlled from a mother space ship that operates in outer space—much like our idea of a satellite vehicle. Reason: reports of saucers seem to come in groupings that have a frequency of about every six months. Something that indicates the earth is in the correct phase of its orbit that would permit a space ship to approach.

The same expert claims that the saucers are unmanned and are therefore capable of sudden terrific changes in direction and speed that would certainly crush a human through "G" forces.

3. Still another school of thought tries to explain the larger flying saucers like the one sighted by an airlines pilot a couple of years ago. Explanation: manned scout ships from a main space vehicle. The airlines pilot (on an Atlanta run) described the object as "a long cigar-shaped vehicle with a double row of lighted windows."

4. According to another former flyer who has made a study of saucer reports, the so-called saucers are not really saucer-shaped. They have the configuration of an egg and fly with the larger end forward.

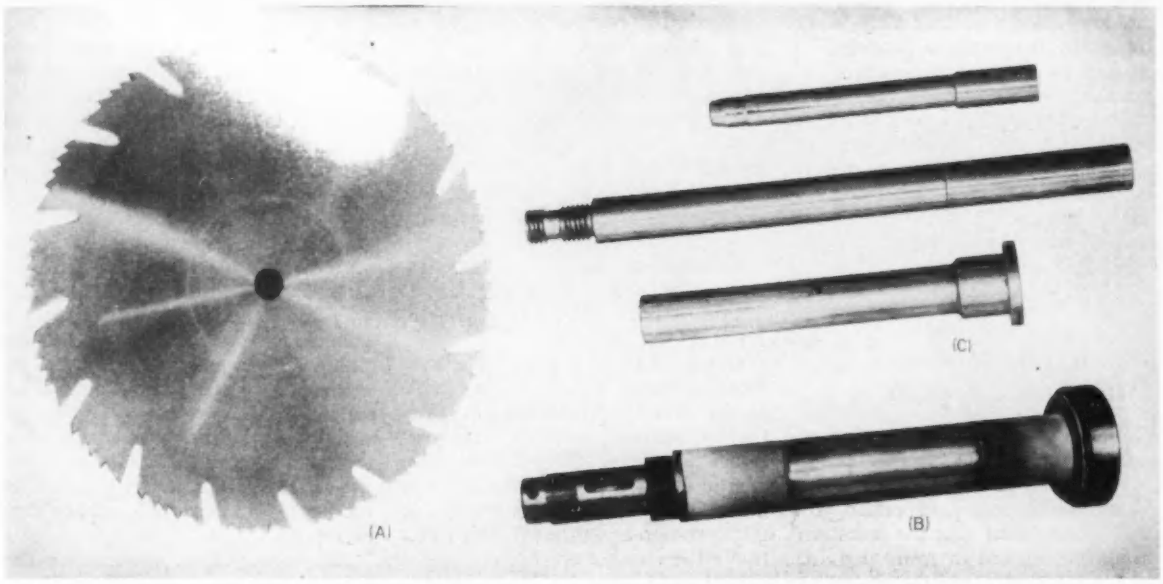
5. A Los Angeles engineer and former Air Force pilot reported seeing a flying saucer that split in half and both halves kept right on flying. He estimated that the saucer was cruising at about 30,000 ft. when the fission occurred.

Air Force Says No

The Air Force counters space traveller claims with the observation that the objects do not follow a reasonable pattern and they fly in a haphazard manner apparently without purpose. Therefore, they could not be intelligently controlled.

Saucer hunters expect that there will be more reports of the flying oddygwoddies, probably when the temperatures start rising again. General Vandenberg, Air Force Chief of Staff, warns against auto-suggestion. He feels that many people see flying saucers because they want to see them.

CHARLES A. HATHAWAY, JR. 1952



TYPICAL PARTS flame-plated with tungsten carbide: (A) saw blade teeth; (B) machine spindle bearing surfaces; and (C) core rods

Processes: Flame Plating Applies Hard Surface

WHEN A MACHINE ELEMENT needs a hard, wear-resistant surface, a designer can specify sintering, electroplating, welding, hard facing, metallizing, or flame-hardening. Now Linde Air Products Company, New York City, has developed a new process that applies powdered metals to metal parts in the form of a coating ranging from 0.0005 in. to 0.020 in. thick, that is resistant to abrasion and friction wear, and has improved resistance to impact and thermal shock.

Linde claims that their "Flame-Plating" process is superior to other hardening techniques because they can prevent any change in the properties of the base since temperatures of the base metal never exceed 355 F. And this coating is mechanically bonded to the base metal, so there is no chance for dilution of the coating.

The company says that the process will work with many powdered metals, but they have concentrated on a method of applying tungsten carbide to precision parts of varied shapes. Composition of this coating is 92 percent tungsten carbide, and 8 percent cobalt combined in complex carbides of tungsten and cobalt.

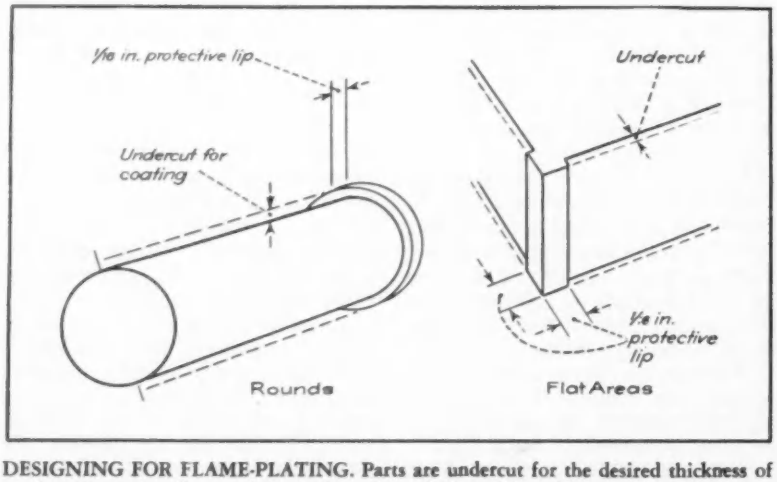
In designing to use the new process, the parts are undercut to allow for the desired thickness of coating. A small protective lip is left at any edge where the part may be subjected to abuse or where two Flame-Plated surfaces are at right angles to each other.

Microscopic study of the coating reveals that the bond between the coating and the base metal is not a welded bond. The base must be deformed to break the bond; if the coating is thin, the coating will crack vertically; if the coating is thick, it will tend to separate from the base on deformation.

Properties claimed for the new coating include a hardness of Rockwell A 89.3; negligible amount of porosity; good resistance to moderate thermal shocks below 2,000 F, since stresses induced during flame plating are low.

Because of the nature of the bond between particles of the coating, the modulus of elasticity is maintained at about 15,000,000 psi as compared to 85,000,000 to 90,000,000 psi for sintered tungsten carbide parts. As a result, light loads cause a slight deformation of the coating and improve wear and abrasion resistance by distributing the load over a larger portion of the bearing surface. Also, if the coating is applied to a ductile metal, it will deform along with the metal instead of cracking when the base metal is under load.

While the coating resists attack by mild alkalis and detergents commonly used in lubricating oils, it cannot be



DESIGNING FOR FLAME-PLATING. Parts are undercut for the desired thickness of coating. Protective lips are left at edges that will be subjected to abuse or where two flame-plated surfaces meet at right angles.

used if the part is exposed to most acids or strong alkali solutions.

Compared to other materials, the Flame-Plating appears to have several advantages. The coating is more ductile than sintered tungsten carbide and can be used economically on parts that are too big or too irregular in shape for sintering. Linde claims that these coatings will last five times longer than sintered tungsten carbide; 15 to 20 times longer than hard chrome plate; and up to 50 times longer than tool steels.

Compared to other methods of producing hard surfaces, the main advantage of this process appears to be in the fact that it is a low-temperature technique. This prevents the base from warping or changing its properties.

However, there are certain limitations to this process in its present stage of development. First of all, the process may not be economical for many manufacturers at this time because the coating must be applied at Linde's Speedway Laboratories in Indianapolis, Indiana, and the round trip of parts is time-consuming and expensive. Linde expects to establish additional facilities for the process throughout the country.

Now prices for the process itself depend on size and shape of the part, thickness of deposit, and number of articles in the run; in general, small parts carry the highest charges per unit area. Typical prices: 70 cents per sq in. for 0.001 in. thick coating on cylindrical articles over 1¾ in. in dia; $10 per sq in. for 0.010 in. thick deposit on cylindrical objects ½ in. in diameter.

This places the cost of Flame-Plating between the cost of a conventionally hard-faced part and a sintered-tungsten carbide.

Another current limitation is the size of parts that can be processed. Present equipment at Speedway limits the size of surfaces that can be treated to 6 in. wide by 40 in. long.

Also resinoid bonded diamond wheels are the only grinding wheels suitable for finishing these coatings.

Linde has applied for a patent on Flame-Plating and is reluctant to divulge the exact method of application until the patent has been granted

Properties of Flame-Plating

Coating	Tungsten carbide (92 percent tungsten carbide, 8 percent cobalt).
Thickness	Maximum 0.020 in; Minimum 0.0005 in.
Base Materials	Tool steels, cast iron, aluminum, copper, brass, bronze, titanium, magnesium.
Hardness	1200–1500 Vickers (300 gram load). Rockwell A 89.3.
Modulus of Elasticity	15,000,000 psi.
Porosity	Less than 0.5 percent.
Tensile Strength	Coating too thin to measure.
Corrosion Resistance	Attacked by most acids and strong alkalis.
Thermal Shock Resistance	Good for moderate shock below 2.000 F.
Mechanical Shock Resistance	Inherently brittle. Can absorb moderate amount of deformation. For best resistance, coating should be less than 0.003 in. thick after grinding.
Surface Finish	125 microinches rms (as coated). 2 microinches rms (after finishing).

Piezo-Electric Element Measures Surface Roughness

AMSTERDAM—Phillips' Works of Eindhoven, Holland, has a new device for solving the old problem of measuring surface roughness. Using a piezo-electrical element of barium titanite that converts surface irregularities to an electrical current, the Phillips roughness meter consists of tester, amplifier, and a meter.

Included with the barium titanite element in the tester is a sapphire needle. As the tester is moved by hand across a surface, the needle follows irregularities and transmits them to the piezo-electrical element where they excite an alternating current. Magnitude of this current depends on the depth of the surface grooves.

This generated voltage is then amplified and rectified before it is measured by the moving coil meter. The meter readings indicate a mean value of the irregularities.

Phillips has developed a special set of standards to be used with the tester. Based on the mean value of the peaks and valleys of the grooves left by the cutting tool after the turning or planing as a measure of roughness, the machine measures in terms of roughness units, (ru.) If the mean value in height is one micro-inch, the surface has a roughness of one ru.

Four chrome-plated sample plates are supplied to calibrate the machine; a "plain-machined plate" has a roughness of 125 ru; "smooth machined," 32 ru; "very smooth machined," 8 ru; and "lapped," 2 ru.

Because of the piezo-electrical element, the tester is so small (about ¾ in. high, and ⅛ in. wide) that the inner wall of ¼ in. hole can be examined. Also, the unit can be modified so it will examine the bottom surface of such a hole.

Although the manufacturer recommends a speed of between two and four inches per second, speed of traversing the surface with the tester does not appreciably affect results.

SPI Sponsors Plastic Pipe Research

TO PROVE THAT PLASTIC PIPE is nontoxic when used in a water transmission system and will not impart a taste or odor to water, the Society of the Plastics Industry, Inc., will sponsor a research evaluation study at the National Sanitation Foundation of the University of Michigan.

Reason for the program is that the public health authorities of some states will not approve the installation of plastic in a water transmission system. In the absence of any authoritative data on the toxicological properties of a plastic pipe, these public health men have been playing it safe and banning plastics.

Estimating that the evaluation will take two years to complete, SPI has asked for tests on Polyethylene, Polystyrene, Cellulose Acetate Butyrate, and Copolymers of Polyvinyl Chloride to get the program started. Other materials will be studied later.

UNIVERSITY OF MICHIGAN LIBRARIES

PLASTIC DIE is placed in boxing fabricated of boiler plate because of high impact resistance required. Plastic punch is in the foreground; lower half of die is in the middle; and in the back, upper half is being lowered to floor for inspection.

Thermosetting Plastic Replaces Steel in Auto Die

FACED WITH HIGHER STEEL PRICE and a shortage of alloys because of the steel strike, the Chrysler Corporation borrowed a leaf from the Aircraft industry (PRODUCT ENGINEERING, April 1952, p 211) and put into production a draw die made of thermosetting liquid phenolic instead of high alloy steel. The plastic die, used in a standard 100 ton press to form steel cowl panels for Dodge trucks, weighs only 1,500 lb compared with 6,000 lb of steel required in old dies.

Big financial savings are realized because of the material and the way the die is made. One half of the die was formed by pouring cold liquid plastic into a plaster mold of the truck panel; to cast the second half, the same mold was coated with wax to simulate the thickness of the finished steel piece.

Since the plastic material generates heat as it sets, its own chemical reaction hardens the die and a 24-hour exposure to the heat of infra red lamps cures the plastic. The die requires no machining after it is formed.

Just as important as the cost saving to the automotive industry, which changes models every year, is the big saving in time required to make plastic dies. Chrysler made their first phenolic die in less than three weeks, compared with 14 to 16 weeks necessary to make a comparable steel die.

Chrysler has formed only a few hundred parts with the new die so they have no data to indicate how the dies will stand up. However, aircraft manufacturers have reported that their plastic dies have almost unlimited life when forming aluminum and stainless steel parts.

While this represents the first use of plastic dies in the automotive industry, airframe manufacturers have been using them for about two years to cut toolmaking time and to improve handling of dies by reducing weight.

Progress Report: How to Purge Fuel Tanks

ONE OF THE SERIOUS PROBLEMS that face air lines and the Air Force is how to minimize the danger of combustible mixture explosions in fuel tanks, surrounding areas, and in engine nacelles. When fuel tanks are full, the danger of explosion is slight; but as the fuel is used, it is replaced by air which absorbs gasoline vapors and forms combustible mixtures. The Ryan Aeronautical Company of San Diego, Cal., is currently investigating for the Air Force methods of preventing explosions and has recently made public a partial report on their progress.

While many of the details have been classified by the military, Ryan was able to indicate in general terms the direction in which they are moving. Two basic plans have been developed for reducing the oxygen content of the space above the fuel and in dangerous areas:

By carrying inert bottled gases like carbon dioxide or nitrogen.

By filling the space with exhaust gases from the aircraft's engine; by carrying a small auxiliary engine whose main purpose is to generate exhaust gases to fill the space above the fuel tanks; or by using exhaust gases from auxiliary power plants.

Bottled gases invoke a serious logistics problem for military air bases because these stations would have to make the gases if this system were adopted. In addition, such a system for a four engine airplane may add as much as 800 lb to the weight of the plane.

On a weight basis, there is not much difference between using nitrogen or carbon dioxide. Carbon dioxide can be compressed to a smaller volume than nitrogen but it requires heavy high pressure containers and could cause an explosion itself if the tank were hit by enemy fire. Nitrogen is lighter than CO_2 but cannot be compressed as much and would require bigger tanks.

Exhaust gas systems look more promising. Logistically superior since it automatically provides a source of inert gases, this method involves a number of technical problems. Before the exhaust gases can be brought into the tank they must be cooled in a heat exchanger and purified by the removal of moisture and corrosive substances. Then they must be distributed at the proper pressure through the dangerous areas. All of these processes require equipment that adds weight.

Ryan has developed a "de-corroder" that removes chemical contaminants

from the exhaust gases so that lightweight aluminum heat exchangers and piping can be used. But the Air Force has not yet decided on which technique to use.

Another opinion on the subject was expressed by R. Tom Sawyer, American Locomotive Company, to the ASME fall meeting. Sawyer claimed the answer to aircraft fuel tank explosions lies in changing the fuel to something similar to that used in aircraft jet engines. Jet fuel is a form of kerosene and is not explosive like gasoline.

Pay-As-You-Go Lightens Tuition Load

IN HOBOKEN LAST MONTH, engineering students got a chance to try out Stevens' Institute of Technology's new "pay-as-you-go" plan, while educators from coast to coast watched the Jersey campus to see if this was the answer to the high cost of a college degree.

In effect, the plan permits a student to pay his college fees in 12 monthly installments instead of two large lump sums. Here is how it works:

Stevens has made arrangements with two local banks who will lend students tuition, dormitory fees, book costs, etc., at low interest. Actually, the banks pay the college the amount of the loan in advance, and the student repays the loan directly to the bank. In this way, Stevens still gets its fees in advance, but the students don't have to make any big payments.

Any student or prospective student can apply for the loan under the plan, and loans are granted on the student's signature, if he is over twenty-one years of age, or on his parent's signature. The banks charge four percent interest and repayments start 30 days after the bank makes the loan.

According to President Jess H. Davis, the most encouraging thing about the plan is the interest that banks have shown. Since announcing the program in July, the college has been swamped by inquiries from financial institutions.

Dr. Davis said, "In their letters, the presidents of several banks have indicated that they have been considering various forms of low-interest loans for college students for some time. This may be a sign that financial circles are at last becoming concerned with a problem that has bothered educators for years: how to enable a deserving student to get a college education regardless of his economic situation."

Manpower Commission Study Urges Better Use of Engineers

FOR THE PAST YEAR, the Engineering Manpower Commission of the Engineers Joint Council has been casting an eagle eye on how industry and the military have been using engineers and not liking what they saw. Last month the Commission decided it was about time that the U. S. realized there was an acute shortage of engineers that was worsening instead of improving and did something about it. The result: 23 pages of observations and recommendations on how to spread the thinning crop of engineering graduates so that industry, government, and the military each get their fair share.

The Commission found two things wrong with existing manpower legislation: laws have been written that do not take into consideration the fact that there is a shortage of engineers and scientists; or if the legislation recognizes this, the bureaus administering the legislation are not following the spirit of the law.

Spokesman Carey H. Brown, Chairman of the Commission, acknowledged that every citizen shares an obligation to serve his country. But he claimed that this service should be where it will do the nation the most good. To accomplish this, he recommended the following immediate action:

- All segments of our economy, governmental and non-governmental, follow the principles set forth in the National Manpower Mobilization Policy promulgated by President Truman on January 17, 1951. This proclamation provided that "Each individual will be expected to serve in the capacity in which he can contribute most to the mobilization program." But several branches of the government, particularly the military, seem to give first consideration to numbers and availability rather than to qualifications.
- In developing programs and plans for national security, mobilizers should give consideration to the value of building up the productive potential and coordinate manpower with this potential. Brown stated that greater productive facilities are more important in providing for successful defense than build-ups of the military in time of partial mobilization.
- Develop and enact into law a practical plan for Universal Military Training with provision to reduce our standing Armed Forces as soon as practical. This period of training should be timed so as to interfere to a minimum degree with education and employment.
- Strengthen the Selective Service System with advisory service to local and state boards so that these organizations will have sufficient facts to make a wise and just selection of engineering personnel in the interest of national security.
- Modify Selective Service regulations so that college students in engineering science and other critical fields can finish their education before being inducted in the same manner as is now being done for those enrolled in ROTC programs.
- Amend the Armed Forces Reserve Act of 1952 so as to provide for the creation of a Civilian Reserve Governing Board, outside the military departments, to establish criteria for and make final decisions concerning the classification and mobilization assignment of reservists having specialized skills and experience.
- Amend the Armed Forces Reserve Act of 1952 to provide for the continued training of scientific personnel without interruption.
- Use the ROTC to train reserve officers needed in technical branches of the service and obtain combat officers through Officer Candidate Schools. Revoke the recent Army and Air Force decision to discontinue technical training in ROTC.
- Establish new criteria for choosing ROTC students so that the distribution of graduates between military and civilian agencies will better satisfy national needs.
- All segments of our economy, governmental and non-governmental, take steps to use engineering personnel to the best advantage by setting up manpower budgets. Move engineering personnel from positions not requiring professional or scientific training, and maintain salary differentials between senior engineers and those newly graduated. (Competition for new graduates has resulted in unprecedented levels of starting salaries, while those of senior engineers have not changed proportionately.)

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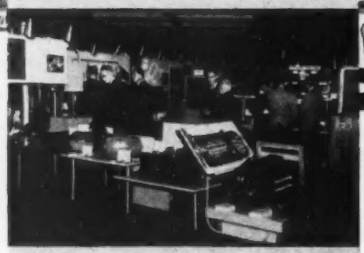
CIRCUIT RIDER (Vol. 6, No. 2, published by Electrical Construction and Maintenance)



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Designing Electric Heating Elements

JOSEPH GIALANELLA
Engineering Research Lab., Amersil Co., Inc.

When designing heaters for continuous operation, the curves shown in Figs. 1 and 2 can be used to determine the size and length of Nichrome V wire required for any given heat load.

In Fig. 1, the recommended B & S gage wire is given with a tolerance of ±2 sizes for 110 and 220 volt operation. Since the resistance of any conductor varies with temperature, cold or room temperature values have been used as the coordinate. This cold resistance is obtained by multiplying the resistance required at the operating temperature by a conversion factor from Table I. For materials other than Nichrome V, similar factors are available from the manufacturers.

When the heating element is formed into a helical coil, the curves in Fig. 2 can be used to find the required closed coil length. These curves are based on the following equation:

$$r = \frac{\pi DR'}{12d}$$

where

r = ohms per in. of closed coil
D = mean diameter of coil, in.
R' = resistance per foot, ohms/ft.
d = wire diameter, in.

As used above, a closed coil refers to a heating element that is compressed solid. In practice, a coil is stretched from 1½ to 4 times its closed length to prevent shorting between adjacent turns and to supply sufficient space between turns for removing the heat.

EXAMPLE

A 2,500 watt immersion heater of Nichrome V wire is required for 110 volt operation. The largest outside coil diameter that will fit in the heater is ¾ inch.

From Fig. 1, the recommended B & S size is 11 ± 2. Using 13 B & S gage wire, the dashed line on Fig. 2 indicates that 16.0 in. of closed coil is required.

The curves in Fig. 2 can be used for materials other than Nichrome V, but the resistance or length of closed coil must be multiplied by the ratio of cold resistives. The resistivity of Nichrome V is 650 ohms per cir. mil-foot.

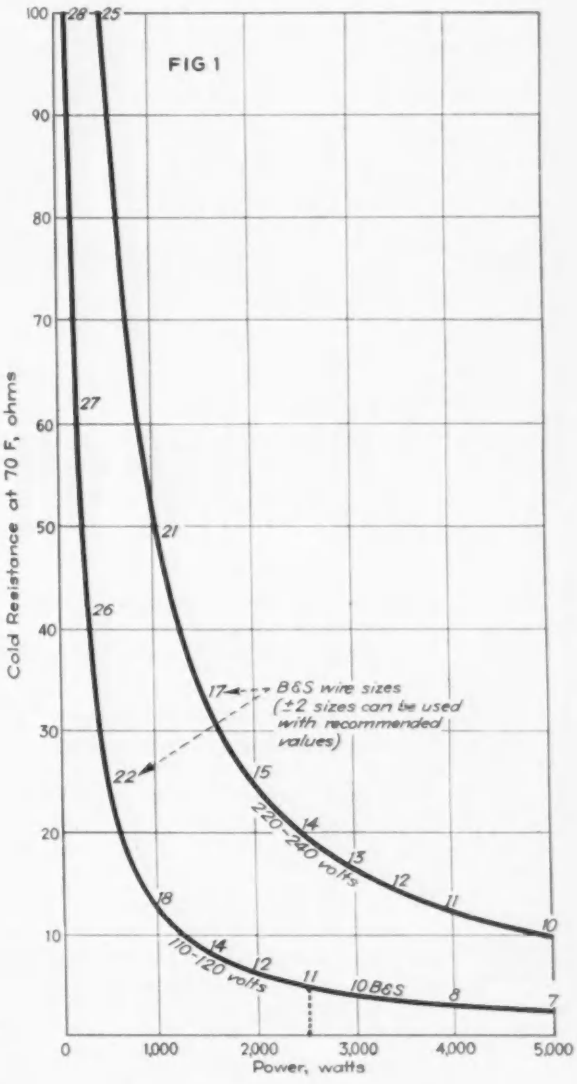

Table I—Conversion Factors For Nichrome V

Operating Temp., F	68	200	400	600	800	1000	1200	1400	1600	1800	2000
Conversion Factors	1.000	0.984	0.964	0.948	0.938	0.935	0.939	0.942	0.938	0.934	0.928

(Continued on page 207)

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Silicone-insulated Wire

Auto-Lite Silicone-insulated Wire is immediately available for use on civilian products — where extreme temperature ranges occur. Check these advantages of Auto-Lite Silicone-insulated Wire for both high- and low-voltage applications.

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Designing Electric Heating Elements (continued)

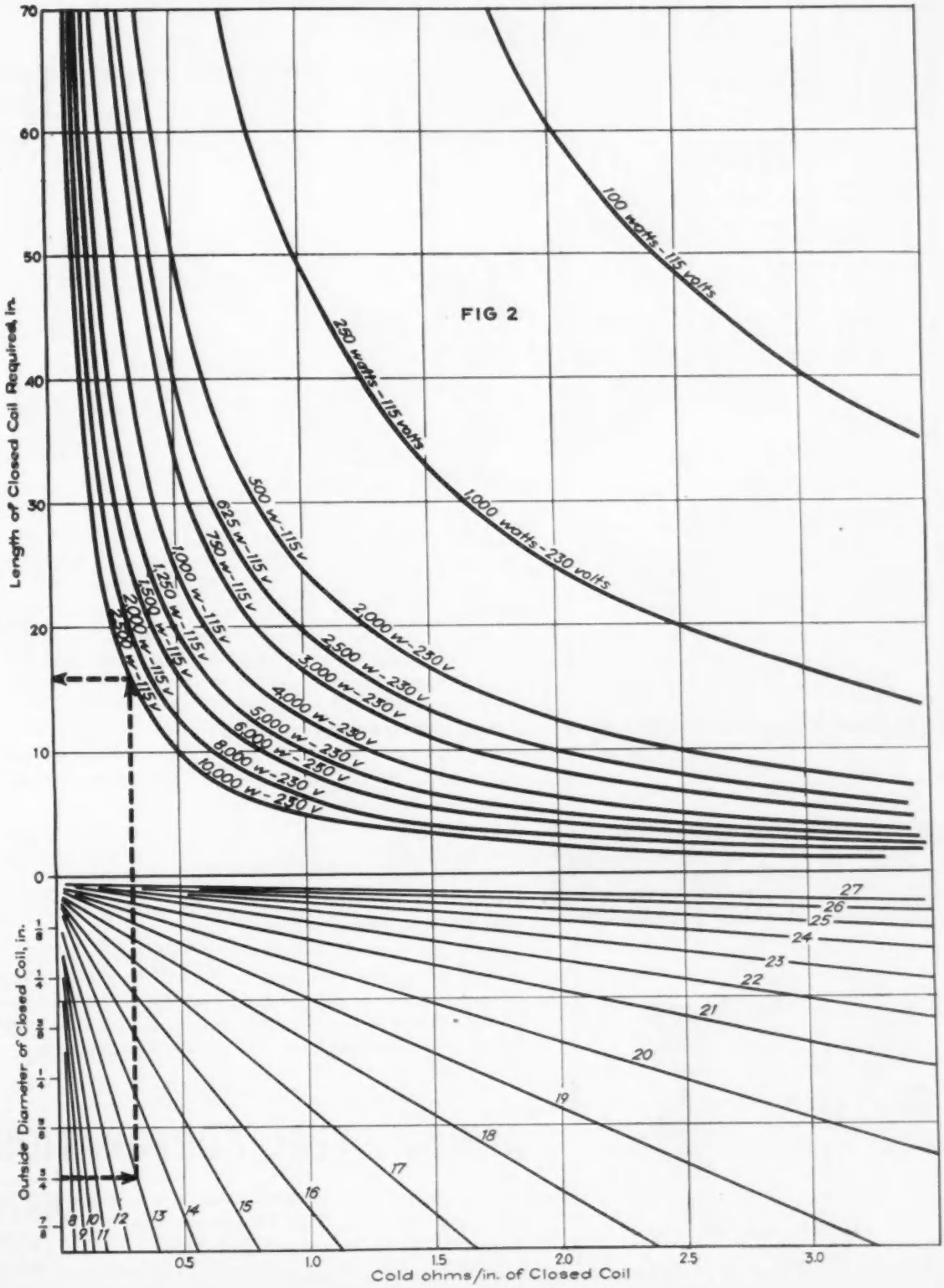
FIG 2
Length of Closed Coil Required, in.
Outside Diameter of Closed Coil, in.
Cold ohms/in. of Closed Coil
100 watts - 115 volts
250 watts - 115 volts
1000 watts - 230 volts
500 w - 115 v
625 w - 115 v
750 w - 115 v
1,000 w - 115 v
1,250 w - 115 v
1,500 w - 115 v
2,000 w - 115 v
2,500 w - 115 v
2,000 w - 230 v
2,500 w - 230 v
3,000 w - 230 v
4,000 w - 230 v
5,000 w - 230 v
6,000 w - 230 v
8,000 w - 230 v
10,000 w - 230 v

Here's a new *Free-Machining* ARMCO STAINLESS STEEL

Here is a part forged from 3-inch round Armco TS 347F before and after machining. Good forging and machining qualities are combined in this highly heat- and corrosion-resistant grade.

Type TS 347F is a new Armco free-machining stainless steel. It was developed to meet the demand for improved machinability in the stabilized Type TS 347, used in jet engine parts subjected to high temperatures.

You may not be building jet engine parts. Yet it is good to know that this free-machining grade, fortified against intergranular corrosion by a columbium-tantalum addition, is now available for applications authorized by NPA.

OTHER FREE-MACHINING TYPES

Besides TS 347F, Armco produces the free-machining types: 303, 416, 420F, 430F and 440F. These grades contain closely controlled amounts of sulfur, phosphorus or selenium. They are used where longer tool life and faster metal-removal are essential. The free-machining grades are indispensable in screw machine work where there are critical drilling and forming operations.

ASK US FOR INFORMATION

Each of the Armco free-machining stainless steels has its field of preferred applications. We will be glad to give our recommendations on the best type for your requirements. If you need general information on speeds, feeds, tool types and the rest, write for a copy of the booklet, "Machining of Armco Stainless Steels."

ARMCO STEEL CORPORATION

4132 Curtis Street, Middletown, Ohio
Plants and sales offices from coast to coast
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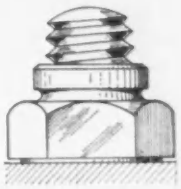
ARMCO

Ordnance Corps Standards for Commercial Safety Nuts

LAMSON

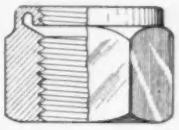
The Lamson & Sessions Co.



Locking collar is distorted into oval shape for two-point locking. Threads in main body carry the working loads.

BOOTS

Boots Aircraft Nut Corp.



Upper section of nut is threaded out of phase with respect to the main portion. It is also designed with limited spring action to provide elasticity.

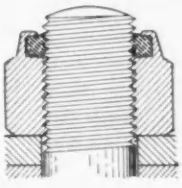
Mac-LEAN FOGG

MacLean Fogg Lock Nut Co.

Closed in threads secured by forming the upper portion of the nut into three-point contact for locking.

ELASTIC STOP NUT

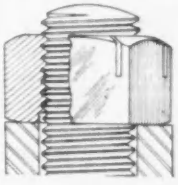
Elastic Stop Nut Corp.



Fiber or nylon insert in the head of the nut has an inside dia smaller than the major dia of the nut. Fiber insert is reusable in accordance with AN-N-5 (15 times on-off); nylon will withstand several hundred cycles.

MARSDEN

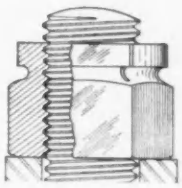
National Machine Products Co.
The National Screw & Mfg. Co.
The Lamson & Sessions Co.
Russell, Burdsall & Ward Bolt and Nut Co.



Upper portion of nut is slotted and the bottom recessed. When nut is tightened against an unyielding seat, threaded upper segments move inward elastically.

FLEXLOCK

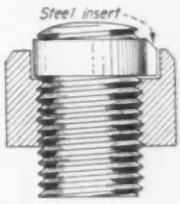
Standard Pressed Steel Co.



Top portion of nut is slotted and the six threaded sections thus formed are closed in on the bolt.

SECURITY

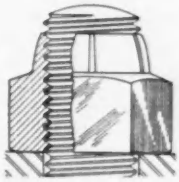
Security Locknut Corp.



A combination of standard nut and an elliptical spring steel insert. Threads on insert and nut body are also misphased. Ear on insert prevents undesired turning.

HUGLOCK

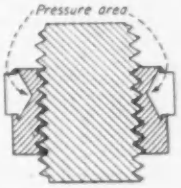
National Machine Products Co.
The National Screw & Mfg. Co.
Russell, Burdsall & Ward Bolt and Nut Co.



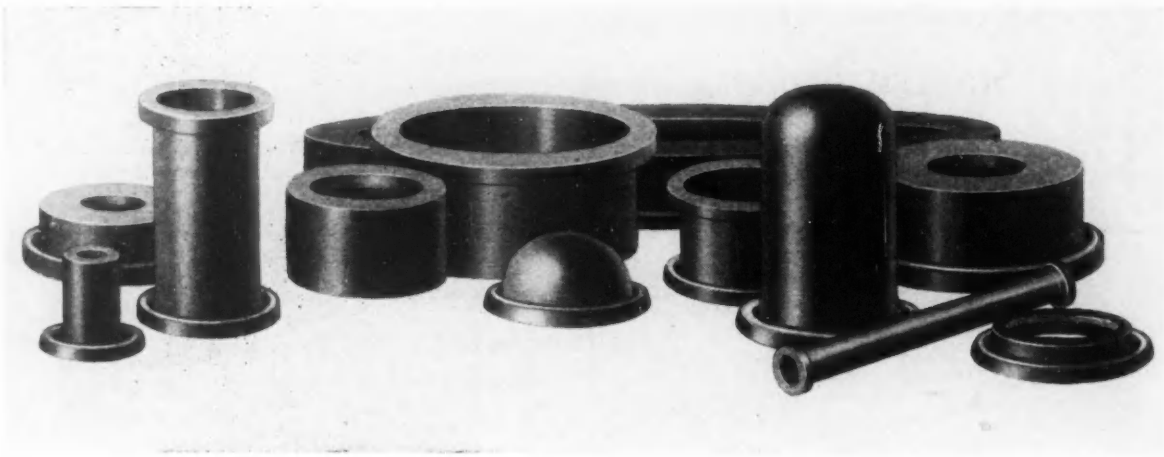
Tapered upper portion is slotted. The curved-in sections gradually engage the bolt threads with a resultant radial and downward elastic force.

STOVER

Stover Lock Nut and Machinery Corp.



Upper part of two opposite flat sides are compressed so that the top of the nut is elliptical, the lower section circular. For identification, top is knurled.



One Piece Molded Elastic Piston Seal

A new, one piece molded elastic piston seal, designed as an alternate for diaphragm or piston operated devices, is a leak-proof, movable seal for all pressures and strokes, and can be incorporated in the design of pneumatic and hydraulic motors, glands, shaft seals, valve seals, cylinders, pumps, brake mechanisms and other devices. At present it is being manufactured in natural rubber, Buna-N, Butyl, and other synthetics for special applications.

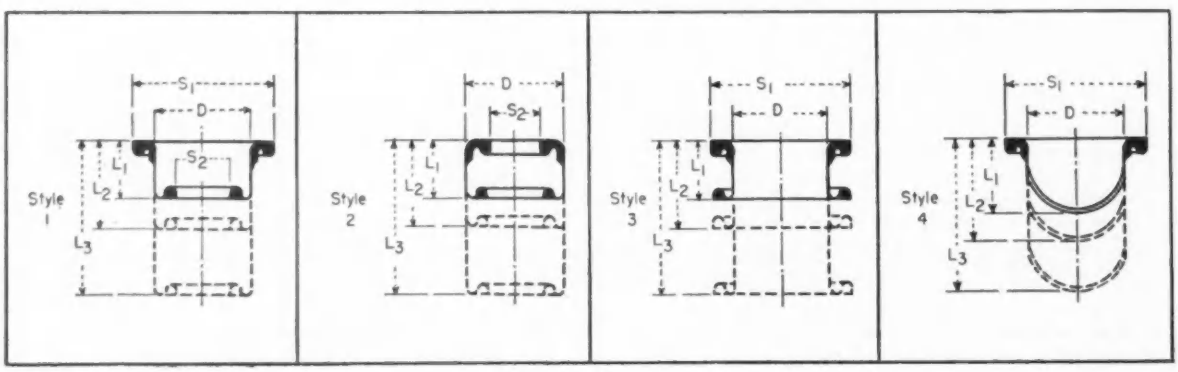
Similar to the conventional diaphragm construction, the hydroseal has a circumferential holding method that uses a peripheral bead for pressure tightness. A cylindrical form of rubber, it will stretch, rather than flex, as in a diaphragm, within the safe limits of the material being used.

The use of this seal in piston operated devices eliminates: close machine tolerances, polishing and honing of cylinders, piston rings and O-rings, and the need for other forms of sealing. Contamination of the hydraulic fluid does not damage the seal.

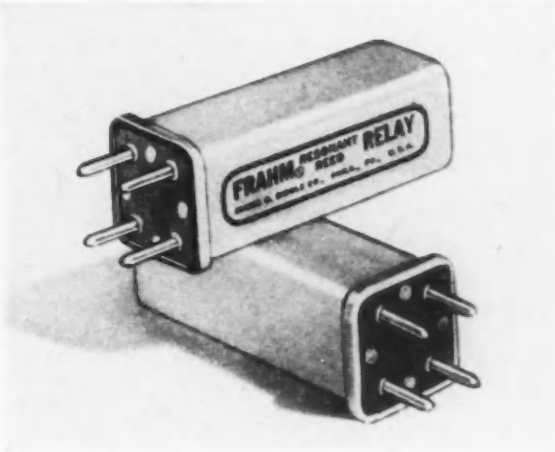
Some of the advantages of the new seal over diaphragms are: same effective area but with about 15 to 30 percent less diameter; positive sealing and absolute tightness; no cloth inserts; little or no maintenance cost, with greater life; burst pressures cannot be compared—a diaphragm may withstand 100 lb pressure, whereas the hydroseal has been used up to 3,000 lb pressure; no leakage around bolt holes; long strokes are possible; the load is supported by metal, while in diaphragms the cloth inserts are always under tension and carry the loading.

Shown below are four styles of end mountings. The dimensions S_1 and S_2 are diameters of the seal, with D the effective area. Dimension L_1 is the free length; L_2 the length at minimum stroke; L_3 the length at maximum stroke. Often L_1 and L_2 are the same. With L_2 being greater than L_1, it develops a preload due to spring rate at a minimum stroke. This preloading (spring rate) is important in application where the motive force is at a minimum, or where the known return stroke is essential.

The Farris Hydroseal Corp., 705 Commercial Ave., Palisades Park, N. J.



Resonant Reed Frequency Sensitive Relay



Based on the characteristics of tuned steel reeds, this resonant reed relay responds to alternating signals having frequencies and amplitude values that are within specified bands. When a proper signal is applied, a reed relay will respond after a few cycles by closing its contacts for a fraction of each cycle.

The transmission of a number of control signals over a single circuit is said to be simplified with reed relays, and their use is not limited to wire circuits but may be extended to all types of communication circuits, including radio.

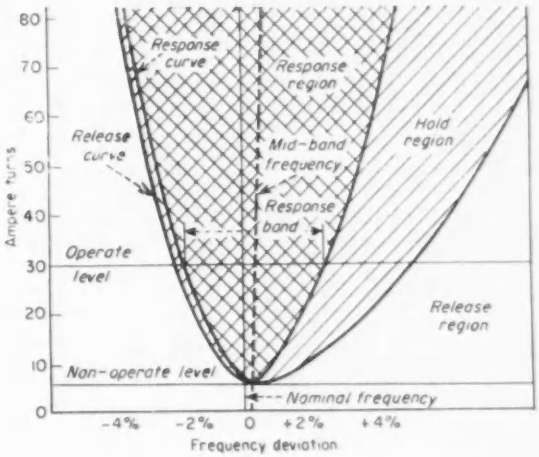
In a typical application, a control function is used to turn off or on a series of low frequency signals (50-500 cps). The signal is transmitted either on a wire line, or as a modulated carrier to some remote location where it operates a reed relay to indicate the control function at that point. Since each relay will only respond to a narrow band of frequencies, it is possible to operate a number of relays simultaneously by making use of an equal number of source generators arranged so that none of the operating frequency bands overlap. In the range of 200-500 cycles it is possible to operate up to 16 channels with no interference between channels.

If a single receiving relay is used for each function, it is possible to handle 16 control functions. When "n" relays are used, the number of control functions which can be handled is equal to the number of combinations of 16 relays taken "n" at a time. Where 4 relays are used 1820 control functions can be handled.

Neglecting transients, the applied signal can be described by two parameters, ampere-turns and cycle deviation, above or below some nominal frequency. These two parameters can be plotted on rectangular, coordinates so that any value of applied signal can be represented by a point. It is then possible to classify certain values of applied signals by the fact that their plotted points lie within a certain area. Any signal that causes a reed relay to respond, will fall within an area on such a plot. This area shown in the graph above, is called the response region, and the curve bounding this area is called a response curve. If a relay is responding, a signal which will maintain the response lies within a larger area called the hold region, which includes the response region.

The relays can be operated at any level between 20 and 200 ampere-turns. At low levels the operating power is about 20 millivolts, while at high levels more than 1 watt may be required. The relay coil will not stand more than 2 watts continuously. For the best operating conditions, the relays should be used at a level between 20 and 50 ampere-turns. At 20 milliwatts the relay will close its contacts within 25 cycles after a suddenly applied signal. At 1 watt, less than 8 cycles are required. Coil resistances available using standard wire sizes and full wound coil forms range from 116 turns at a resistance of 0.40 ohms to 10,000 turns at a resistance of 3,500 ohms.

James G. Biddle Co., 1316 Arch St., Philadelphia 7, Pa.



No. Turns	Resistance	A.W.G.
116	0.40	24
175	0.83	26
250	1.57	27
360	3.40	29
480	6.0	30
620	10.0	31
675	12.7	32
910	22	33
1,150	35	34
1,350	55	35
1,780	85	36
2,200	132	37
2,600	200	38
3,300	330	39
4,200	530	40
5,000	800	41
6,100	1,180	42
7,800	2,000	43
10,000	3,500	44

CONTINUED ON PAGE 212

Signaling Type Temperature Controller

For accurately controlling operating temperatures ranging from minus 100 F to plus 600 F, newly designed Thermo Electronic temperature controllers using resistance bulb sensitive elements are built with single or duplex control action, and are available in six different temperature ranges. The standard resistance bulbs, designed for use with these controllers, cover practically all process applications. The instrument has a relay with load contacts for operating heating elements, motor starters, electric valves, and signal contacts for the two red and green lights on the instrument door. These signal lights are visible over a wide angle at distances up to 100 feet.

When the temperature at the resistance bulb deviates as little as 0.1 F from the control point setting, the instrument takes rapid corrective action. The control action is continuous. The electrical measuring system eliminates time lags in transmitting temperature changes from the senstive element to the instrument.

To take advantage of the responsiveness of the controller, all thermo electric resistance bulbs have small volume and mass and solid contact between the winding and the outer housing.

The calibration of the measuring circuit is accurate within ±0.25 percent of the scale range. This accuracy is maintained by stabilized manganin wire resistors and does not depend upon mechanical parts. Variations of the a-c voltage, or variations in resistance of the connecting cable from bulb to instrument do not reduce calibration accuracy. The circuit is not affected by electrical interference from induction heaters, spot welders, or smaller apparatus. Relay chatter is eliminated by lock-up circuits.

The control relay is the only moving part in this instrument, which operates completely on a-c current. All auxiliary or trimming adjustments, periodic standardizing or battery replacements are eliminated. Standard vacuum tubes are used in the electronic circuit. Controllers are suitable for flush panel or wall mounting, require no leveling, and need not be mounted in a vertical position.

Thermo Electric Co., Inc., Fair Lawn, N. J.

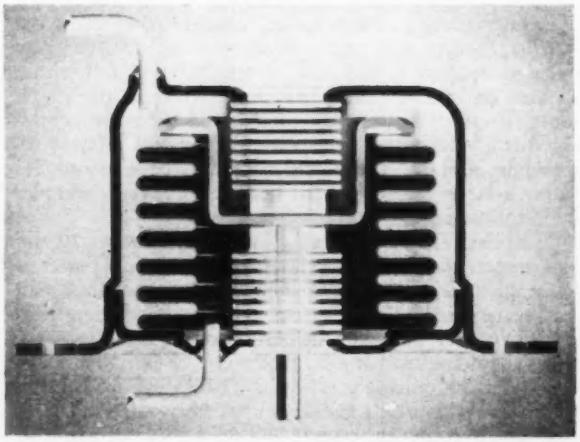
Single Unit Bellows for Differential Pressures

A type of single unit bellows assembly for differential pressures, originally developed for jet plane fuel systems, makes possible the maintenance of absolute pressure by means of a single-unit control. In operation, two different pressures are applied to the opposite sides of the large bellows in the center of the unit. One tube allows pressure to be exerted against the inside surface of the bellows, the second tube permits pressure to be applied to the outside surface. Since the pressures inside and outside the large bellows are acting on the same effective areas, the resultant force produced by the difference between the inside and outside pressures can be utilized through the center of the unit to actuate switches or valves or other controls. The two smaller bellows are used to seal the ends of the main bellows.

This single unit assembly can be used in the manufacture of thermostatic or pressure switches, which must not be affected by barometric changes due to altitude or other factors. This is also true of pressure thermostats.

The unit is said to be useful for flow indication or control. Pressure drop across an orifice or venturi can be used to "sense" flow in a closed system.

The manufacturers recommend the new unit for all industrial processes in which the pressures within a closed system must be automatically equalized, or where absolute pressure rather than gage pressure must be maintained.



The Clifford Mfg. Co., 152 Grove St., Waltham 54, Mass.

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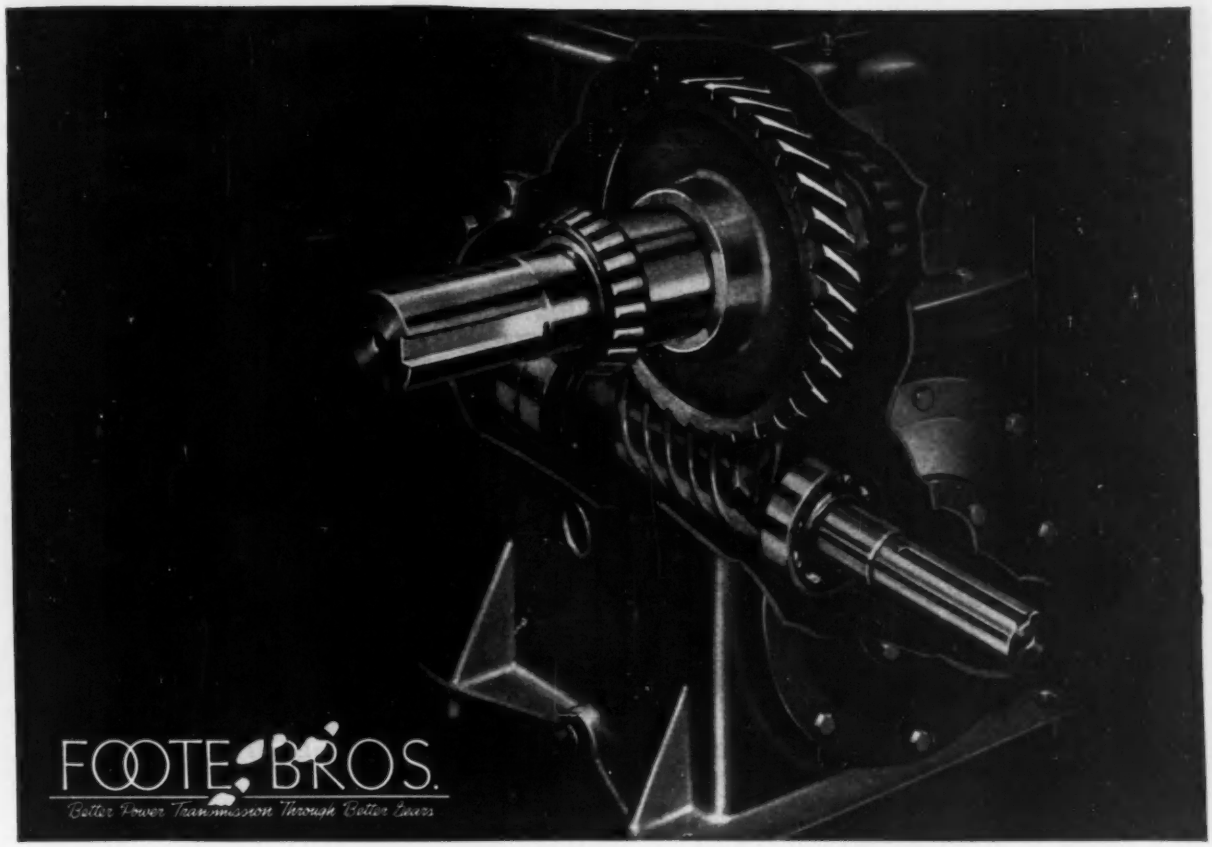


a matter of confidence

Specialists who designed this speed reducer entrusted production of its bronze worm gear blank to other specialists.

Foote Bros. Gear and Machine Corporation, Chicago, leading producers of Speed Reducers, Gears, and other quality Power Transmission Components for practically any industrial requirement, identify themselves with the phrase "BETTER POWER TRANSMISSION THROUGH BETTER GEARS."

For over twelve years, Foote Bros. have purchased thousands of ½ pound to 1500 pound non-ferrous gear blanks from National Bearing Division—confidently entrusting their reputation and industry leadership to special foundry skills for which National Bearing is famous.

And Foote Bros. confidence is well placed.

National Bearing's proven ability to mass produce exceptionally fine-grained, non-ferrous castings, free from blow holes and sand inclusions, can be depended upon under even the most exacting engineering and manufacturing specifications.

As a typical customer service-plus, National Bearing Division's engineers and foundrymen recently designed, and produced for customers like Foote Bros., a bronze gear blank that contains even higher physical properties.

Through a new foundry technique, National Bearing imparts greater hardness, finer grain, and more tensile strength to the bronze gear blank ring, to a depth below where the teeth are cut. In addition, this new process gives such extra advantages as higher uniformity, closer tolerances, and economy of stock.

If your product requires special mass-produced non-ferrous castings or bearings, National Bearing Division has the foundry facilities, experience, and skill that will insure better product performance, and may possibly lower product costs through production-run economies. You are invited to write to National Bearing Division for complete information.

Brake Shoe

NATIONAL BEARING DIVISION

4932 Manchester Avenue • St. Louis 10, Mo.

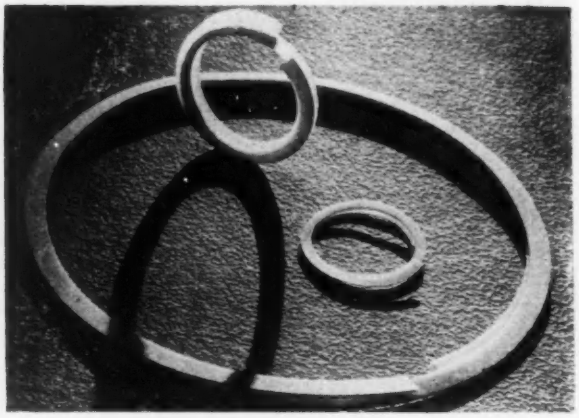
PLANTS IN: ST. LOUIS, MO. • MEADVILLE, PA. • NILES, OHIO • PORTSMOUTH, VA. • ST. PAUL, MINN. • CHICAGO, ILL.

UNIVERSITY MICROFILMS

Back-Up Seals for Hydraulic O-Rings

A new-type spiral back-up ring for O ring seals for hydraulic service, that will not shrink, swell, harden or soften, is made of a packing known as Kelon-T, and is said to protect the O ring seal indefinitely from extrusion, deterioration, or loss of efficiency. Chemically inert, the new packing has low-friction, is unaffected by oils, acids, bases or solvents, and has a useful temperature range of from —110 F to +500 F.

The Kelon-T spiral packings are used most often as back-up rings to extend the life of rubber O rings in hydraulic and pneumatic cylinders, presses, pumps and valves, but new aircraft and industrial applications for the new packing have been found. It is said to be possible, in some applications, to seal effectively without O rings if the packing completely fills the groove in one continuous spiral of several layers. Sizes of the standard spiral packings range from 0.125 to 15.50 in. I.D., and correspond with sizes of standard O rings. The rings are available in 153 sizes with special sizes available on order.



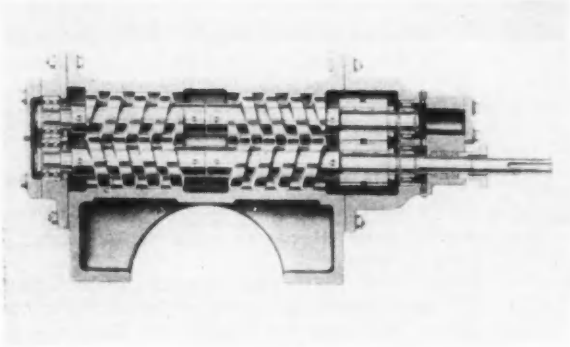
W. S. Shamban & Co., 5747 Marilyn Ave., Culver City, Calif.

Internal Gear and Bearing Type Screw Pump

An internal gear and bearing type screw pump for positive displacement of lubricating fluids or semi-fluids has capacities ranging from 1 to 700 gpm, and discharge pressures of 1,000 psi for viscous liquids, and 500 psi for light oils. The pump is a companion product to the bracket type screw pump, external gear and bearing type.

Features of the new internal gear and bearing type are: the heavy duty roller bearings just inboard of the timing gears where radial load is heaviest; lock nuts behind the timing gears for easier repairing; and double-row angular contact ball bearings at the rear end which position the rotors axially for less year on the bearings and timing gears.

Other advantages are: interchangeable rotor screws for easy over-hauling; no metallic contact between the rotors for long rotor life and continued high volumetric efficiency; only suction pressure on stuffing boxes; direct connection up to 1,800 rpm for use with high speed motors.



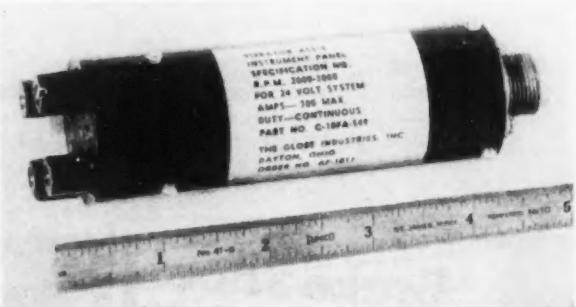
Sier-Bath Gear & Pump Co., Inc., 9252 Hudson Blvd., North Bergen, N. J.

Fractional Horsepower Motor Used with Vibrator

A new panel vibrator is designed to introduce a vibration of known frequency and amplitude into instrument panels, and to increase meter accuracy and prevent sticking.

The vibrator is an electrically driven device operating continuously, with the motor power being furnished by a fractional horse power motor operating at any standard d-c voltage. The motor is a two-pole, two-brush design with an unbalanced weight mounted on the end of the armature shaft. Weight gives the vibration action of the assembly. Shaking forces, at 2,500 rpm, can be provided from 0.85 lb to 3.4 lb by varying the weight. The frequency is 2,000-3,000 cpm.

The weight of the unit is approximately 10 ounces, the actual size on the photo. An integral circuit is used for the purpose of eliminating radio frequency interference.

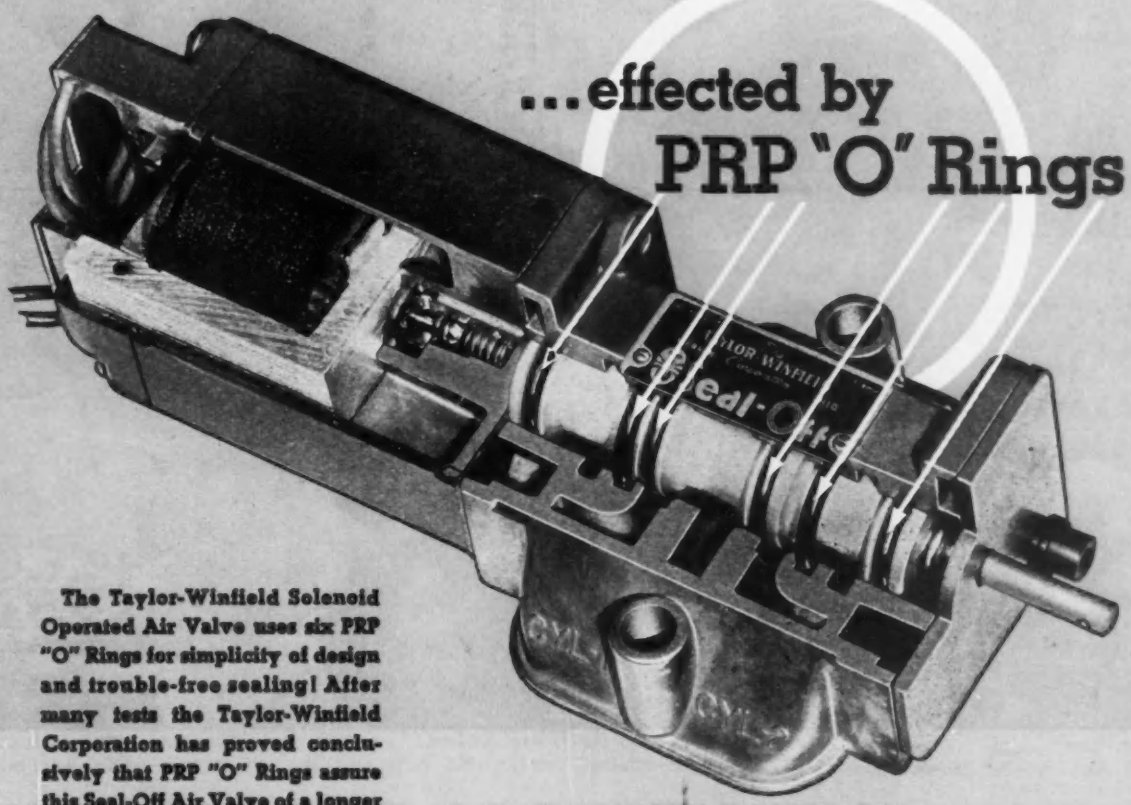


Globe Industries, Inc., 125 Sunrise Place, Dayton 7, Ohio

CONTINUED ON PAGE 216

HERE'S SIMPLICITY AND SMOOTH SERVICE!

...effected by PRP "O" Rings

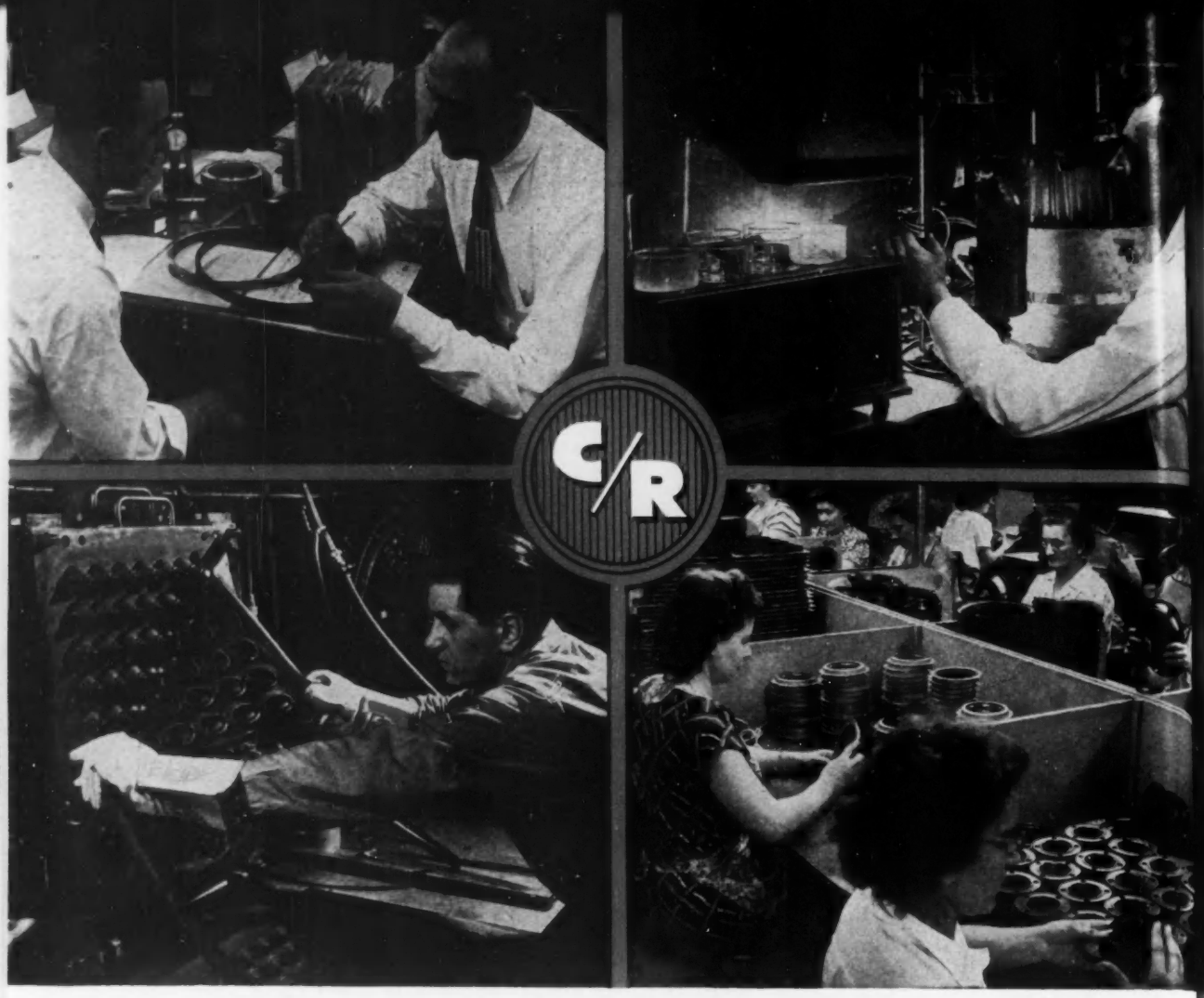


The Taylor-Winfield Solenoid Operated Air Valve uses six PRP "O" Rings for simplicity of design and trouble-free sealing! After many tests the Taylor-Winfield Corporation has proved conclusively that PRP "O" Rings assure this Seal-Off Air Valve of a longer operating life at higher rates of intermittent or continuous duty performance.

Everyone's finding it's PRP "O" Rings for top quality, long life and economy. Count on our experienced field engineers for expert "O" Ring advice. Write or phone . . . ask for your free copy of our Handbook of design information.

The name "Precision" on "O" Rings is like "sterling" on silver

Precision Rubber Products
CORPORATION
The "O" Ring Specialists
Dept. 3, Oakridge Drive, Dayton 7, Ohio



FOUR MEANS TO AN END

The end is this: a molded synthetic rubber part, designed exactly right to fit your mechanism; produced with the correct resistance and physical properties to suit your specifications; and delivered with the assurance of completely satisfactory performance.

Chicago Rawhide offers you four important means to achieve this end. They are: 1) Cooperation with your design department to check all phases of the Sirvene part while your new mechanism is still on the drawing board; 2) The facilities of C/R research, with an unduplicated background of experience, for the development of the particular compound that will have the combination of properties correct for your application; 3) Production in quantity, with laboratory-like care and precision; And, 4) Delivery of finished parts that will verify in performance each of your specifications.

Sirvene is your best assurance of satisfaction!

Cooperative research and engineering which Chicago Rawhide has provided in helping other leading manufacturers develop special Sirvene synthetic rubber parts are available to you. We will be pleased to send you a copy of "Engineering with Sirvene."

CHICAGO RAWHIDE MANUFACTURING CO.
1299 Elston Avenue SIRVENE DIVISION Chicago 22, Illinois

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Mechanical Leather Products
Boots, diaphragms, packings and other products give dependable service under difficult operating conditions.

PERFECT Oil Seals
C/R seals are used in more motor vehicles, farm implements and industrial machines than any other shaft-type sealing device.

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SCIENTIFICALLY COMPOUNDED ELASTOMERS

Representatives in These Principal Cities: Boston • New York • Syracuse • Philadelphia • Pittsburgh
Cincinnati • Cleveland • Detroit • Peoria • Minneapolis • Kansas City • Milwaukee • Los Angeles • San Francisco

High Pressure Hydraulic Cylinder and Components

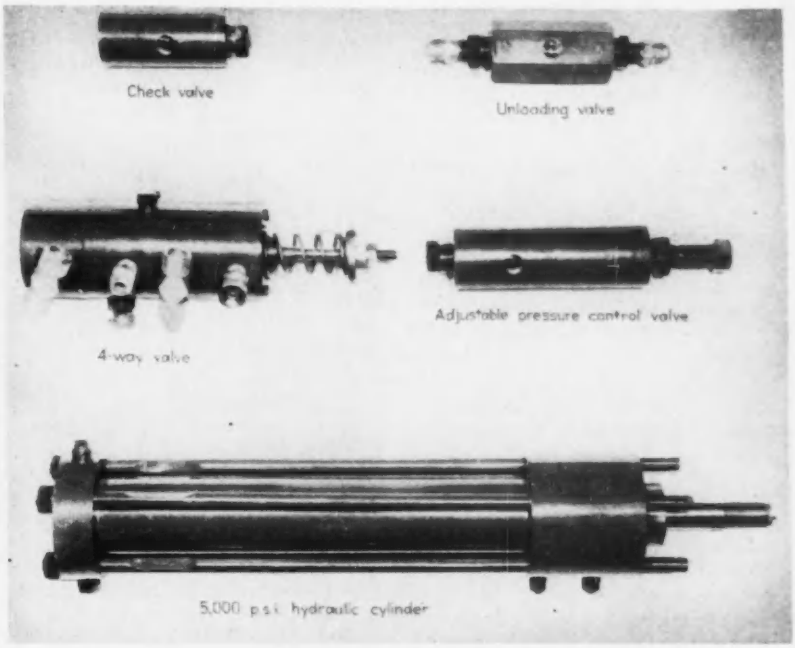
High pressure hydraulic cylinders with 5,000 psi operation are made with a screw type bronze packing nut having a double seal feature with a drain back to the reservoir to eliminate seepage at the piston rod. A felt wiper in the packing nut wipes the piston rod as it moves back into the cylinder.

The piston is wide for long bearing surface, and cast rings are used with felt wipers ahead of the rings to wipe the walls of the cylinder, reducing cylinder scoring.

Cylinders are made with: flange mounting for the dome end; flange mounting for the piston rod end; base mounting; rod extension; and the pivot type. Cylinder bores are from $1\frac{3}{8}$ in. to 6 inches. The packing on the piston rod is a combination leather and sirvene (rubber).

The 4-way valves are of all steel construction with a 4 way spring offset with external drains; a 4 way spring centered with external drains; felt wipers to protect the stem and body; and has a capacity of 5 gals per minute.

The unloading valve is used for a low pressure pump in a high pressure system to discharge low pressure fluid to the tank after a pressure of 500 psi is reached, or for charging the accumulator. The unit is of all steel construction with removable ball seats and all $\frac{3}{8}$ NPTE connections.



The adjustable pressure relief valve is for 5,000 psi operation with 2 outlets for the tank. It has removable trapped ball seats, and static seal O-rings.

The free flow check valve is of all steel construction, operates at 5,000 psi, has removable trapped ball seat, $\frac{3}{8}$ in. NPTE connections, and a 5 gal per min capacity.

For more information on these components, contact the manufacturer.

Munton Mfg. Co., 9400 Belmont, Franklin Park, Ill.

Double Seated Diaphragm Regulating Valve

A new double seated diaphragm regulating valve, class DV, has been developed for use with control instruments, and will meet all the features required by process industries.

The flow-line shaped body has been designed to give ISA standard face-to-face dimensions with the highest capacity, lowest turbulence, and body pressure drop.

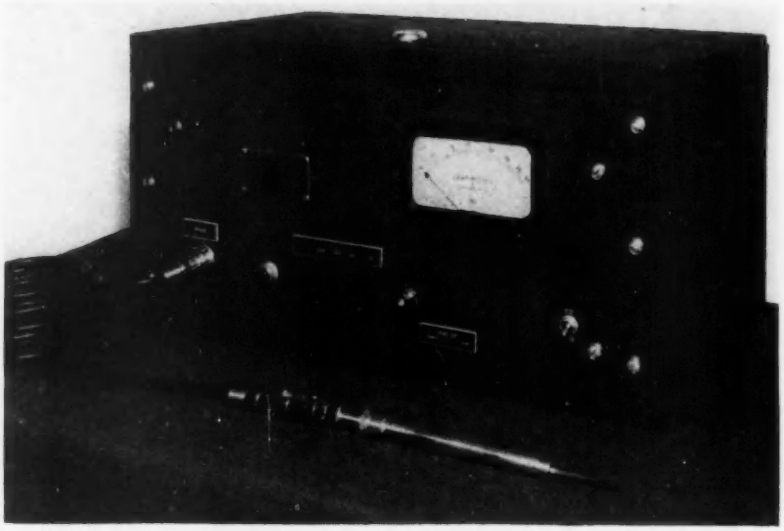
Another feature is the renewable interchangeable seat rings. The rings are machined so that they can be removed and replaced without removing the valve body from the pipe line. It also eliminates elaborate grinding operations at high temperatures. The main valves and seat rings of the valve are furnished with stellited seating surfaces. In steel valves the seat rings are eliminated, and the stellite applied directly to the main body. Other trims without stellited seating surface are also available. A choice of four standard trim materials are available: types 316, plain or stellited; 440c hardened stainless steel; bronze trim.

The valve action is easily reversed in the field without changing or machining any parts. Having a wide range, it has good control of wide flow requirements with high CV numbers. Four sizes of superstructure are available, with from 50 to 210 sq in. of effective area, designed to operate on 3-15 psi air used with standard instrument controllers. The valve is available in sizes from $1\frac{1}{2}$ to 10 in., for pressures up to 600 psi, with screwed ($1\frac{1}{2}$ and 2 in.), and flanged ($1\frac{1}{2}$ - 10 in.) ends. Cooling bonnets for temperatures over 500 F and under 30 F.

Leslie Co., 345 Delafield Ave., Lyndhurst, N. J.

CONTINUED ON PAGE 218

Computer Automatically Measures Viscosity



The ultra-viscoson, a unit consisting of a probe and an electronic computer, is used for continuous, automatic viscosity measurement using ultrasonics. The viscosity is determined by the use of ultrasonic waves applied to the probe. The electronic computer converts the probe output instantly into viscosity measurements on the meter, recorder, or controller.

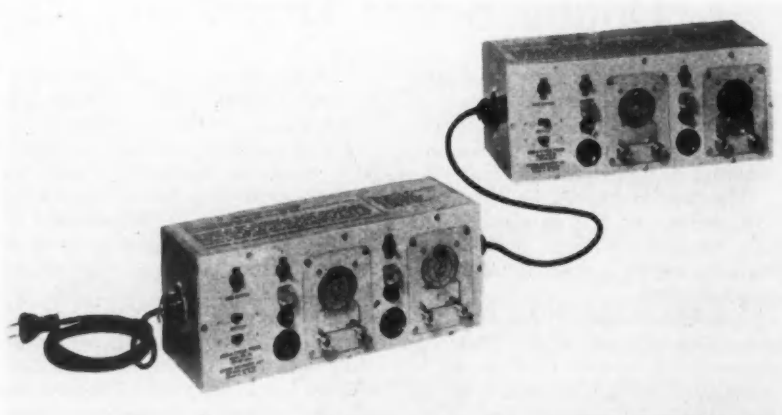
The hermetically sealed probe is the size of a fountain pen, has no moving parts, operates from —109 F to +650 F. up to 500 psi, is installed permanently in pipe lines, production kettles, or used in test tubes and beakers. The electronic computer, located up to 1 mile from probe, indicates viscosity of newtonian materials from 0-50,000 centipoises x grams/cc. in 4 decades—0/50/500/5,000/50,000. Apparent viscosity x density of some non-newtonian materials of high viscosity may be measured over this range. Connection to recorder or controller gives continuous charts or automatic control. It may also be used to actuate automatic systems for dumping batches at desired viscosity or for continuous process control. The minimum sample required is 4 cc of liquid.

Measurement of viscosity at a number of stations is accomplished by using a separate probe at each station, and an ultra-viscoson multiplex computer. Manual multiplex switching units permit each probe to be switched in and read on the meter. The automatic multiplex unit connected to a recorder automatically records the viscosity measured at each station separately on a single convenient chart.

The device may be used for manufacturing and research in petroleum, resins, paper, plastics, starch, gelatine, foods, textiles, soaps, printing inks, coatings, finishes, blood plasma substitutes, and medicines.

Rich-Roth Labs., 673 Connecticut Blvd., E. Hartford 8, Conn.

Cycling Timer Has Wide Range of Time Cycles



The add-a-cycle timer has been developed for the testing of components and for other operations where it is desirable to have a wide range of time cycles available. Set-up time is reduced to a minimum through the use of plug-in adjustable timers, which are supplied in sixe overlapping ranges, from 1.5 - 12 seconds to 15 - 120 minutes. Therefore, it is possible to have adjacent cycles with widely varying time limits.

The add-a-cycle is furnished as a basic unit having two plug-in positions, and any number of them may be cabled together and will cycle as a group, so that an unlimited number of time cycles may be obtained. Normal rating is 10 amperes, 115V, 60 cycles, but special ratings may be obtained.

For process timing the add-a-cycle is built in wall mounting cases with any required number of adjustable plug-in time cycles, which allows flexibility and permits easy servicing. An additional feature is that any cycle may be skipped without loss of time in the event any part of the process is temporarily out of use. The timer is finished in gray hammered lacquer.

The Becker Equipment Co., 3020 N. Cicero Ave., Chicago, Ill.

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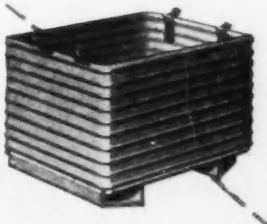
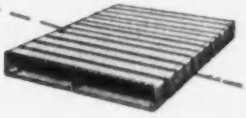
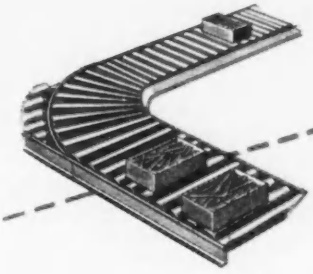


Handle materials better, more cheaply, with equipment made of



N-A-X

HIGH-TENSILE STEEL



Minimum product weight and long product service are just two important reasons why N-A-X HIGH-TENSILE steel is ideally suited for tote boxes, pallets, conveyors, lift trucks, and other equipment used for transporting materials.

Because N-A-X HIGH-TENSILE steel has exceptional strength and durability, thinner sections can be used, yet it resists abrasion, impact, fatigue, and corrosion. N-A-X HIGH-TENSILE steel gives your equipment longer life and reduces deadweight to the minimum; you can carry a greater net load of material with no increase in the gross load weight. And N-A-X HIGH-TENSILE steel has exceptional welding and fabricating qualities – important advantages where custom-made materials-handling equipment is required.

If you are interested in better, more economical materials-handling, why not investigate N-A-X HIGH-TENSILE steel *now?*

MAKE A TON OF SHEET STEEL GO FARTHER
Specify—
N-A-X
HIGH-TENSILE STEEL
... And "MAKE YOUR PRODUCT LAST LONGER"
SCRAP STEEL

GREAT LAKES STEEL CORPORATION

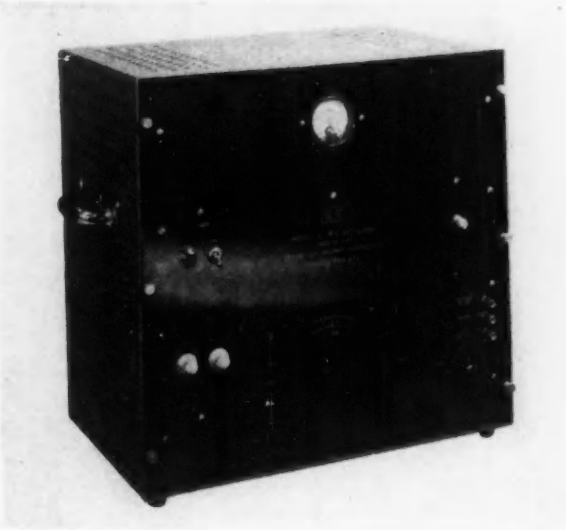
N-A-X Alloy Division • Ecorse, Detroit 29, Michigan

NATIONAL STEEL CORPORATION

Low Frequency, Low Distortion Oscillator

A new model L low frequency oscillator designed as a source of signal power in the range of 0.01 to 100 cps, features the use of passive elements (resistors and condensers) for frequency determination, and is said to offer excellent short and long time frequency stability. The circuit has been treated as a d-c amplifier, and both plate and filament supplies have been carefully regulated. The output circuit is directly coupled to the load and will produce 20 v or 20 milliamperes into any load impedance. The unit is a true sine wave generator, and the wave shape is said to contain only low order harmonic distortion.

Two separate means for amplitude control have been provided. An oven-controlled thermistor is used as a quasi-linear element where low distortion is required (in the order of 0.1 of 1 percent). A varistor is also provided in a circuit which allows it to control the amplitude by creating 1 percent or less distortion (primarily third harmonic). Since the non-linear amplitude controlling element does not involve the quantity time, there is no amplitude bounce associated with its controlling action.



Southwestern Industrial Electronics Co., 2831 Post Oak Rd., Houston 19, Texas

Edgewound Resistor For High Current Duty

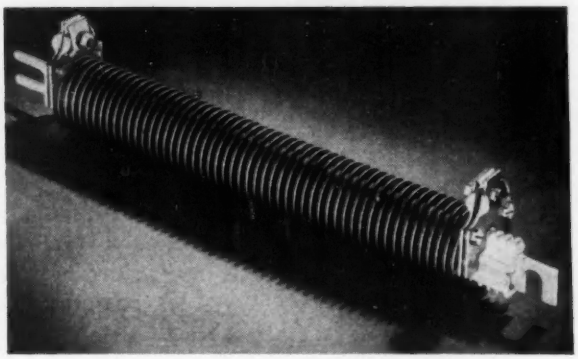
Powr-Rib, a new edgewound-type resistor, designed for high-current duty in both intermittent and continuous applications, will give high heat dissipation, resistance to oxidation, and the ability to withstand shock and vibration without breaking or shorting.

These resistors are suitable for original equipment or for replacement in existing installations, where high-current and good heat-dissipation characteristics are required. They are particularly applicable in electric trucks, battery chargers, motor controllers, load banks, plating and welding equipment, as well as motor starting, plugging, field discharge, and dynamic braking in d-c controllers.

The resistors are wound with a heavy ribbon of resistance alloy on a ceramic insulator. All other metal parts are specially plated to prevent oxidation at high operating temperatures and to give good electrical contact. The ceramic insulator is divided into five sections to give the required flexibility and resistance to shock and vibration.

Extra terminals can be ordered for adjustable taps. An optional sleeve is available, which permits the mounting bar to expand without buckling.

On the mounting bar of the new resistor is a longitudinal slot allowing the mounting center to vary between 16¼ and 17 inches. Thus the unit is able to replace any standard edgewound resistor.



The resistors are available in resistance values from 0.100 to 2.85 ohms. They are rated at 707 F temperature rise. Capacities range from 18.0 to 108 amperes.

Ohmite Co., 4823 Flournoy St., Chicago, Ill.

THE LINEAC, an electrical analogue computer for the solution of linear simultaneous algebraic equations, both scalar and complex, uses no amplifiers, and has the feature that the solution is obtained immediately without any repititious process, either manual or automatic. It may be used in reverse for the simulation of linear functions, which are the sum of a number of terms, each of which is the product of a variable and a constant. It consists of multi-coil tapped transformers and a voltage divider, and operates on 60 cycle voltage. For well-conditioned matrices of the order of ten or so the error is a fraction of one percent, and this accuracy can be extended to higher orders with compensating adjustments. American Hydromath Corp., 145 W. 57th St., New York 19, N. Y.

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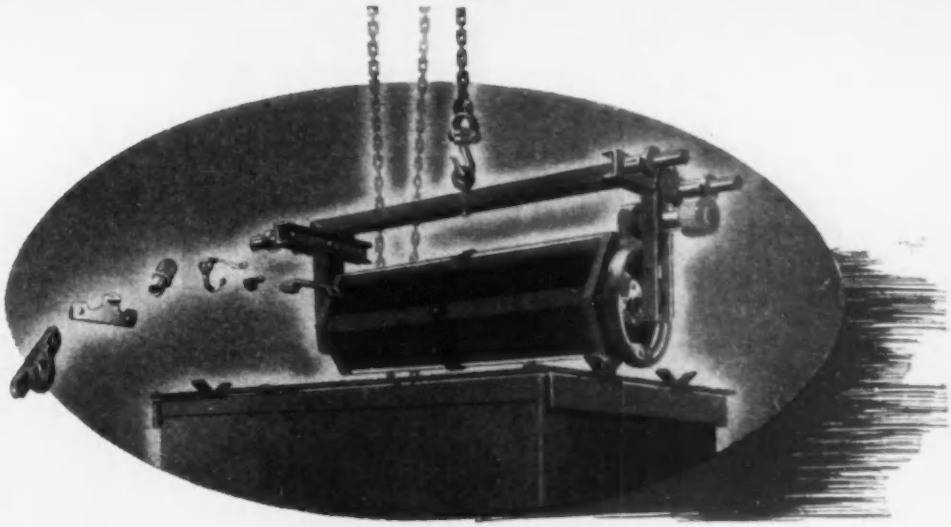


Plating on Aluminum made EASY with Alumon

Hundreds of manufacturers throughout the United States are now using electroplated aluminum. The Alumon process is simple. The work is merely cleaned, dipped in acid, dipped in Alumon and is then ready for electroplating with copper, nickel, and other metals. The process is suitable for plating most wrought and cast alloys. . . The cost of using Alumon is low, being less than half a cent per square foot of surface area treated. The process can be fitted easily into regular plating cycles. Bulk or barrel plating readily done. Upon request we'll gladly send you the Alumon Process Bulletin.

Write for literature on Alumon and check list of literature on sixty Enthone products and processes for better metal finishing.

*TRADE-MARK REG. U. S. PAT. OFF. MANUFACTURED UNDER U. S. PATENT 2,142,564.

METAL FINISHING PROCESSES

ENTHONE
INCORPORATED

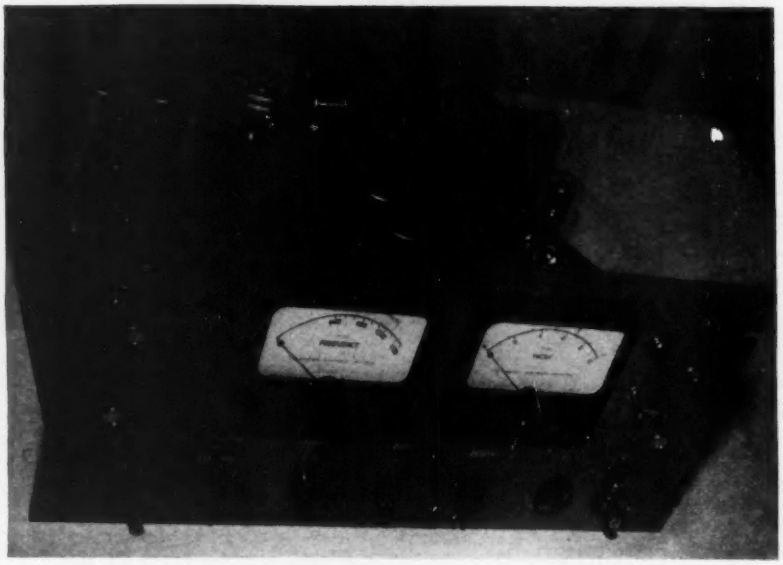
ELECTROPLATING CHEMICALS

442 ELM STREET
NEW HAVEN, CONNECTICUT

Special Magnetic Materials In WOW Meter

The type 152A Wow-Meter is a direct indicating instrument measuring both the frequency variations, (wow), and the center frequency of an audio signal. It is designed to measure wow in the center frequency range 800 to 1,250 cycles. The built-in frequency meter is calibrated in the range 600 to 1,500 cycles. Other corresponding ranges may be obtained on order to frequencies as high as 10,000 cycles with higher wow ranges if desired.

The frequency and wow-measuring circuits use a new principle of operation based on the characteristics of special magnetic materials and recent developments of this company. The techniques used involve a static frequency-to-voltage translating unit that produces an output voltage directly proportional to the input frequency and independent of the signal amplitude. The frequency-metering section responds directly to the translator d-c output voltage. The wow-metering section consists of an a-c coupled peak-to-peak reading voltmeter with suitable filters and range switching to allow selection of the sensitivity and wow spectrum measured. The available full-scale wow sensitivities are 0.3, 1.0, and 3.0 percent.



Three wow spectrums are available: $\frac{1}{2}$ to 10, $\frac{1}{2}$ to 120, and 10 to 120, with appropriate damping for each range, and a meter reset switch for use on the more highly damped ranges. Outputs are provided for independent monitoring of frequency and wow, allowing connections to recording equipment to record the center frequency and the wow continuously, and the attachment of a spectrum analyzer or oscilloscope to examine the waveform of the frequency variation (wow). An internal, stable, wow-free 1,000 cycle oscillator is used as an aid to rapid measurements of recording systems. The instrument has a complete dual-regulated power supply.

Minnesota Electronics Corp., 47 West Water St., St. Paul 1, Minn.

Subminiature Toggle Switch Assemblies

A series of small toggle switches designed primarily for use in assemblies where precise switching components must be located in small space, are primarily for aircraft use, but also have industrial applications.

One assembly (identified as 6AT2), is shown at right and is a single-pole, double-throw assembly which uses one 1SM1 switch riveted into a stainless steel toggle bracket. Another (6AT3) shown at left, includes two basic 1SM1 switches and gives double-pole double-throw service.

Electrical ratings of the 1SM1 basic switch in these assemblies are given tentatively as: motor or resistive load, 2 amp 30 v d-c; inductive load at sea level, 2 amp 30 v d-c; inductive load at 50,000 ft, $1\frac{1}{2}$ amp 30 v d-c; 5 amp 125 or 250 v a-c.

The overall dimensions of the 6AT2 assembly are 25/32 in. long, 1-21/64 in. high and 25/64 in. wide. Overall dimensions of the 6AT3 with two subminiature switches are 25/32 in. long, 1-21/64 in. high and 21/32 in. wide. *Micro Switch, Freeport, Ill.*

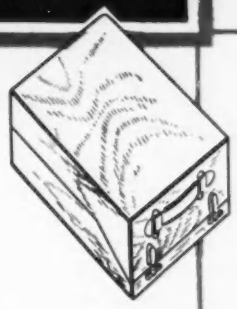
CONTINUED ON PAGE 224

marion's NEW metertester

MODEL M-2

MEASURES SENSITIVITY AND RESISTANCE

for testing and calibration of D. C. instruments in the laboratory and on production lines



Marion's New Metertester (Model M-2) retains proven Marion features but increases application flexibility. In addition to improved circuitry for sensitivity measurement it also measures internal resistance of sensitive instruments without exceeding full scale rating of the instrument under test.

FEATURES

- Regulated Power Supply
- Stepless Vacuum Tube Voltage Control
- Illuminated 8½" Mirror-Scale Standard Instrument, Hand Calibrated
- Marion Ruggedized Null Indicator movement for bridge balance indication
- Decade of .1% accurate Manganin Wire Wound Resistors
- Direct Reading Bridge Circuit using Helipot
- Complete. No accessories required

SPECIFICATIONS

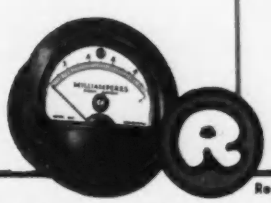
ACCURACY: Overall better than ¼ of 1%
RESISTANCE RANGE: 0-5000 ohms
POWER SOURCE: 115V A C 60 cycles
CASE SIZE: 15⅛" x 10⅛" x 5⅜"
WEIGHT: 15 lbs.

SENSITIVITY RANGES

0-25UA	0-200UA	0-800UA	0-10 MA
0-50UA	0-400UA	0-1 MA	0-100 Volts
0-100UA	0-500UA	0-5 MA	

The New M-2 Model can also be used for additional purposes, such as a precise source of DC current and voltage and as a precision Wheatstone bridge in the 0-5000 ohm range.

For further information write Marion Electrical Instrument Co., 415 Canal Street, Manchester, N. H., U. S. A.



marion meters

Reg. U.S. Pat. Off.

MANUFACTURERS OF RUGGEDIZED, HERMETICALLY SEALED AND STANDARD PANEL INSTRUMENTS

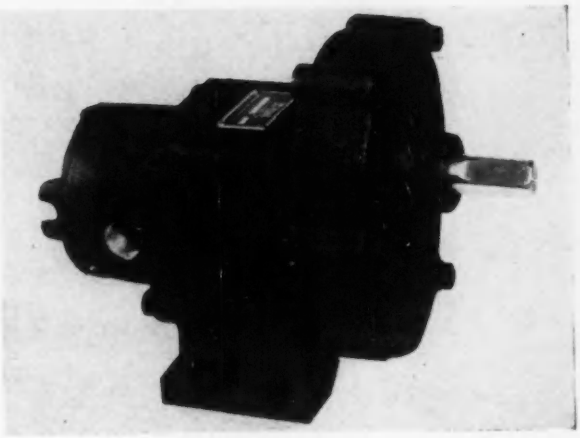
Tachometer Heads for Measuring Low Speeds

Heavy duty tachometer heads for measuring low speeds, either rotational or linear, may be used for measuring speeds of extruders, welders, kilns, conveyor belts, ovens, dryers, and other installations where the head shaft is rotated between 1 and 99 rpm for full scale indication.

The tachometer heads consist essentially of a step-up gear train, a head element, or a polarity reversing switch, and a capacitor. The switch is actuated, through the gear train, by rotation of the head shaft so that polarity connection of the capacitor is reversed at a frequency greater than, but proportional to, the rpm being measured.

The gear train is a 2 stage spur gear type, with the low speed stage a 32 diametral pitch, and the high speed stage a 48 diametral pitch.

Operating temperature range is −50 F to +200 F. Maximum radial load is 75 lb; max. shaft thrust is 100 lb.



Metron Instrument Co., 432 Lincoln St., Denver 9, Colo.

Sensitive Electronic Control Relay

An electronic control relay, designed to operate in conjunction with a differential transformer transmitter, is being produced in several types for use with pressure, flow, motion and force.

To get control of any variable, the differential transformer is adjusted so that its zero position is at the exact point at which control is desired. This position is sensitive to less than 0.0001 in., and as the armature of the transformer is moved off this null point by a change in the variable, a signal is generated having amplitude and phase definition. The control relay is sensitive to this minute signal and either pulls in or drops out.

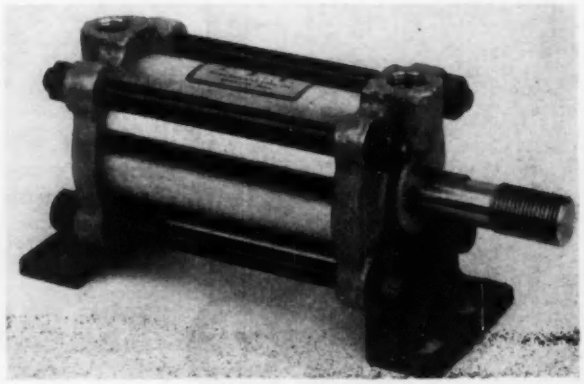
Operation of control relay is not affected by normal line voltage variations and can be installed up to 5,000 ft away from source of measured variable. As it is a sensitive device, the relay will operate in both directions repeat cycle, or one direction repeat cycle.

Automatic Temperature Control Co., 5200 Pulaski Ave., Philadelphia 44, Pa.

Air Cylinders Feature Easy Installation

A new line of double and single acting air cylinders are offered with bore sizes from 1½ through 6 inches. Stroke lengths are available from 0 to 24 in. in increments of 1/32 in., with special bore diameters and stroke lengths made on request. The pressure range for these units is up to 150 psi.

Features incorporated in these cylinders include: cylinder walls of hard drawn brass tubing on all bore sizes; manganese bronze end castings on bore sizes up to 4 inches. High tensile cast iron end castings are used on the 4½ in. and larger diameter bore sizes; high tensile rust proofed tie rods; O ring rod end seals, and neoprene rubber piston cup packings to reduce air leakage to a minimum; hard chrome plated piston rods to reduce wear and corrosion.



Bond Research Labs., Inc., 84 Winslow Ave., Somerville 44, Mass.

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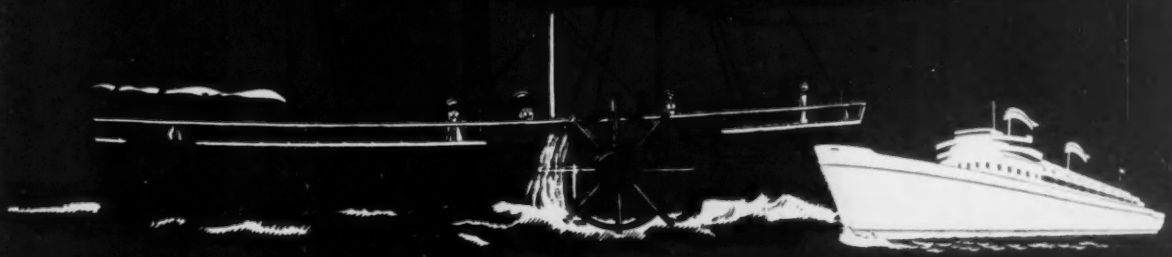
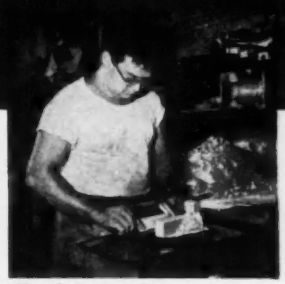
ANTIQUATED...





Hand Coremaking

IS YOUR Pattern Equipment JUST AS ANTIQUATED?

Shortly after the famed Clermont made navigation history, Seth Boyden established his pioneer malleable iron foundry. Today, Sacks-Barlow, direct descendants, continue to assist industry's efforts for new operational economies by eliminating antiquated methods.

The antiquated hand box above, for instance, makes but one core at a time . . . a slow and inefficient operation; at the right however, is an example of improved technique—by using a blower core box, 4 instead of 1 cores are made simultaneously.

At Sacks-Barlow every effort is made to analyze each order to determine the most efficient and economical process to be used for molding and coremaking. Our "know-how" based on 126 years' experience producing gray, malleable and ductile iron castings is at your disposal—without obligation.

Sacks-Barlow

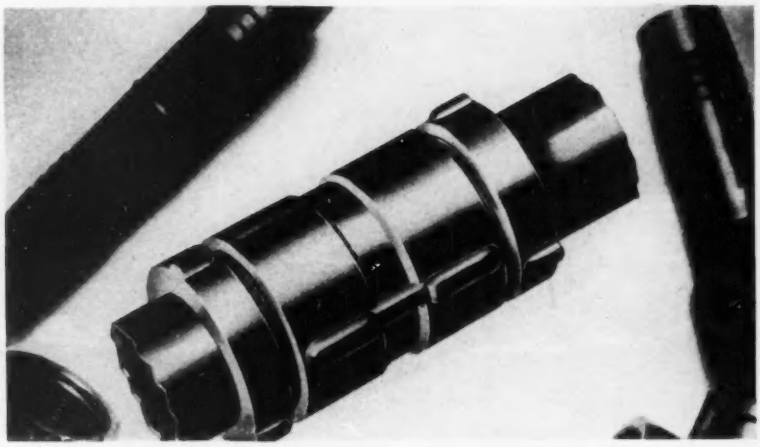
Rigid Plastic Pipe and Compression Fitting

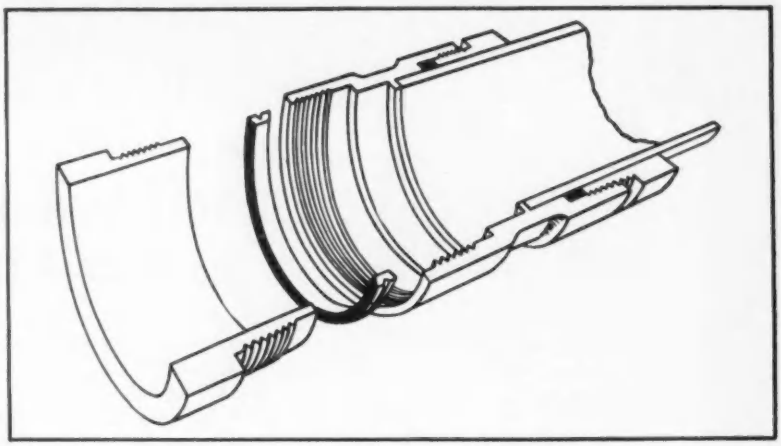
An improved rigid plastic pipe, and a new compression type coupling has increased resistance to burst, high tensile and flexural strengths, high chemical resistance, and long life expectancy.

This type L plastic pipe has an ultimate tensile strength of approximately 6,000 psi, and an effective tensile for piping applications of 3,600 lb per sq in. at room temperature. Flexural modulus is 250,000 psi, and impact is 4.3 Izod (notched). Burst pressure varies according to pipe diameter (1 in. dia has burst pressure of over 1,000 psi), and is sufficiently great for installations with moderately high pressures.

This lightweight plastic pipe can be handled and installed quickly and is supplied in 10 and 20 ft random lengths which can be connected by means of the new compression type coupling or by slip-sleeve tees and ells. With the new type fitting, a longitudinal force exerted on the rubber gasket in the fitting creates a secondary force at right angles to the first in order to maintain a positive leakproof joint at all times. This new coupling compensates for the expansion and contraction of rigid pipe. The slip-sleeve ell and tee fittings form an interior shoulder to which the pipe is butted. Finally, a special cement is applied to the outside of the pipe and the throat of the fitting to give a leak-proof joint.

The new plastic pipe is available in standard sizes from ½ to 2 inches.





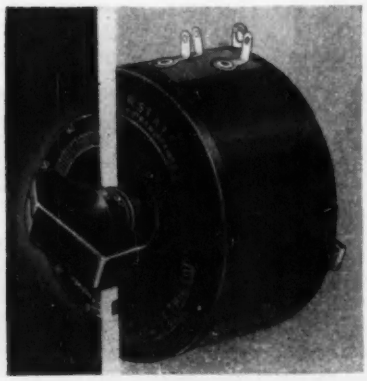
Carlon Products Corp., 10225 Meech Ave., Cleveland 5, Ohio

Small Size A-c Voltage Control

Said to be the smallest physically and electrically of any variable transformer, a new variable a-c voltage control of 50-100 and 150 watt loads measures 3 in. in diameter, and has a depth of 2 1/16 inches.

Like other models of the powerstat made by this company, the type 10 is an autotransformer of toroidal core design with a movable brush-top. Rotation of the brush-top delivers any desired output voltage from zero to, or above, line voltage. Adjustment to fractional voltages is stepless. As it is a transformer it does not control by dissipating power in the form of heat. Also, it does not have to be tailored to the load; it will deliver a variable voltage to any load up to its rated capacity.

The type 10 is rated at 120 v, 60 cycles, single phase input, with an output of 0-120/132 volts, 1.25 amp, 150/165 VA. Other characteristics include a glass smooth commutator surface, zero waveform distortion, and improved core and coil design. This model is tapped to allow an output voltage range from zero to line voltage, or to 10 percent above line.



The Superior Electric Co., Bristol, Conn.

CONTINUED ON PAGE 228

MACHINERY MFR. REPORTS ON WORLD-WIDE SERVICE OF

STERLING SLO-SPEED!

88% of the bulk packing of dried fruits throughout the world is done on our Eagle Automatic Weighing and Packing Units which are powered by Sterling Slo-Speed Drives, reports Mr. Oren G. Mosher, Factory Manager of Eagle Machinery Co., Ltd. We have used Sterling Drives for 14 years because of their outstanding dependability, high efficiency, and ability to carry heavy over-hung loads without damage or wear on the bearings.

STERLING SLO-SPEED GIVES YOU THE ONE BEST LOW SPEED AND

gives uninterrupted service—carries heavy overhung loads—provides versatile mounting and flexibility in arrangement of machinery—saves valuable space—provides greater safety—costs less to install and use. An indispensable source of low speed power for:

Agitators	**Dryers**	**Presses**
Blenders	**Feeders**	**Pumps**
Blowers	**Kilns**	**Screens**
Conveyors	**Mills**	**Tumblers**
Cookers	**Mixers**	**Etc., etc.**

OTHER STERLING ELECTRIC POWER DRIVES:

- **STERLING SPEED-TROL (VARIABLE SPEED) MOTORS**
- **STERLING KLOSD AND KLOSD-TITE (NORMAL SPEED) MOTORS**

DRIP-PROOF • SPLASH-PROOF • TOTALLY ENCLOSED

70 ILLUSTRATIONS showing how Sterling Electric Power Drives reduce production costs. Write for Bulletin No. C-107

STERLING ELECTRIC MOTORS

Plants: New York City 51; Van Wert, Ohio; Los Angeles 22; Hamilton, Canada; Santiago, Chile.
Offices and distributors in all principal cities.

Long Life Radiation Detector

A new radiation detector, known as the Radector, uses the ionization chamber, an invention that will make possible the measurement on a single scale, from ordinary background radiation to over 1,500 R/hr.

For purposes of civil defense, the Radector has been designed to measure from 0.02 R/hr to 500 R/hr on a large, easy-to-read, single logarithmic scale. Powered by only 4½ v, without the need of amplification, it has eliminated such components as vibrators, voltage regulators, condensers, high megohm resistors, and transformers.

Measuring only 5 x 3 x 3 in., and weighing two pounds, the device fits in the palm of the hand. It has a performance record of 168 hr of continuous use with no drop in meter reading. Battery life is almost equal to its shelf life. Accuracy is within less than plus or minus 10 percent of radiation intensity. No warm-up time is necessary.

Jordan Electronic Mfg. Co., Inc., 9042 Culver Blvd., Culver City, Calif.

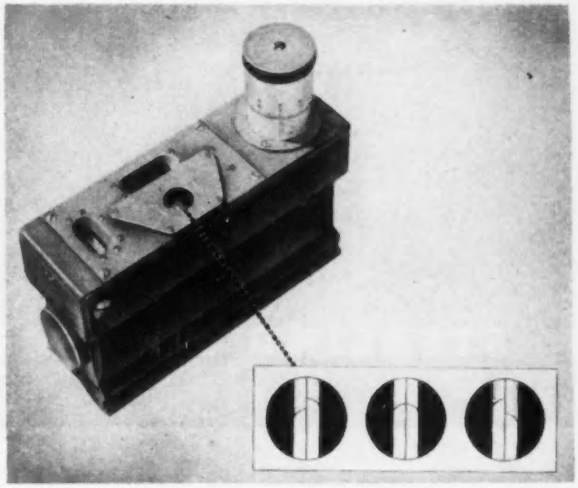
Sensitive Optical Level Measuring Device

A newly developed optical level for measuring flatness, straightness and parallelism reads deviations from the horizontal of 0.00012 in. per foot of length, or 0.00001 in. per inch of length. This accuracy makes it possible to check the flatness of surface plates and machine tool beds, the straightness of cylindrical rolls, and the parallelism of V-ways or flats to values with the closest working tolerances.

Critical measuring and leveling operations can be performed, and there is no limit to the length of work that can be checked. By moving the level along a surface 7 in. at a time (the length of the instrument), or in shorter increments, and by taking a series of readings, the entire length of the surface can be checked and plotted on graph paper.

Applications include leveling and checking operations such as: inspecting flatness conditions of machine beds, surface plates, ground shafts, paper and dryer rolls, jigs, fixtures, airframes, lofting, lapping plates, and checking spindle arbor runout.

The optical system consists of three bubble phials and two prisms so arranged that twice the usual accuracy of level reading is obtained. The amount and value of deviation from the true horizontal in the work piece being examined are measured by means of a large diameter graduated micrometer thimble and barrel. The illustration shows half images of opposite ends of the air bubble as seen in the master phial. When the images form a perfect semicircle (center) the true horizontal has been established. Separated images indicate deviation from the horizontal; rise (left) and fall (right).



F. T. Griswold Mfg. Co., W. Lancaster Ave., Wayne, Pa.

A SERIES OF LOW COST retainer springs of "hairpin" type may be substituted for cotter pins, locknuts, and other uses. Retention is obtained by snapping the spring into the shaft groove. The series has 15 springs for use with shaft groove diameters ranging from 3/32 to 15/16 inch. Manufactured of Spring Steel Wire these retainers will stand repeated assembly and disassembly without appreciable loss of spring quality. Precision Spring Corp., 800 W. Broadway, Three Rivers, Mich.

A SERIES OF SMALL RESISTORS designed to meet the miniaturization program of the armed forces, aircraft, and electronic industries, have resistance values from 20,000 ohms to 2 megohms, and are available in sizes from ¼ in. dia by 1⅜ in. long. Maximum resistance may be obtained with various types and sizes of wire. Daven Co., 191 Central Ave., Newark, N. J.

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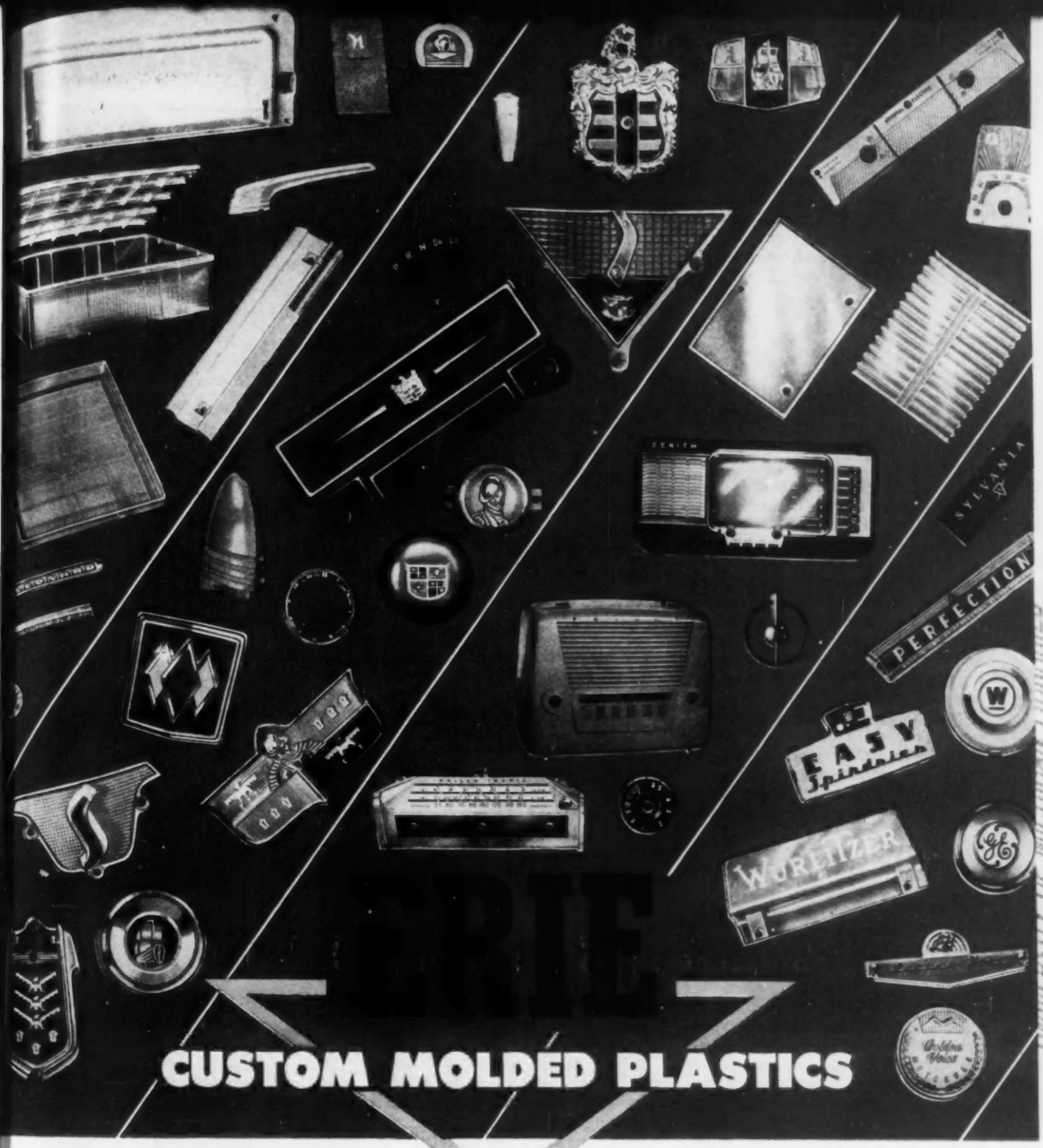

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Pieces that require exacting tolerances . . . interchangeable parts, mating parts, threaded parts . . . Erie can meet any difficulties you may have with solutions that have been proven in production.

Erie Three Dimensional Plastics, used as decorative trademarks or name plates, or embodied in functional parts, are truly breathtaking in their imperishable beauty.

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ERIE RESISTOR CORPORATION . . . . . PLASTICS DIVISION

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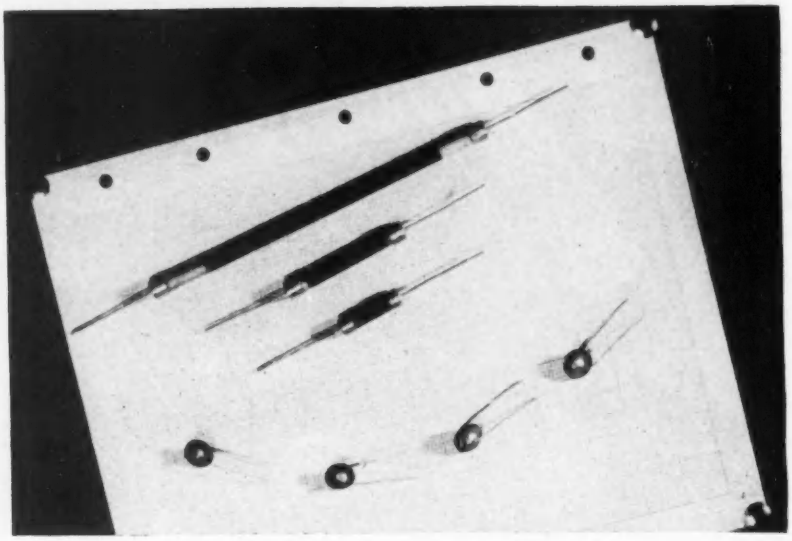
Factories: **ERIE, PA. • LONDON, ENGLAND • TORONTO, CANADA**

New Line of Miniature Resistors

Expansion of a line of miniature resistors to give greater coverage of the volt-ampere characteristics range, has resulted in miniature resistors, whose electrical resistance decreases with increases in applied voltage, and can be used as a stabilizing influence on circuits supplied by rectifiers, for control of voltage selective circuits, and for protection against voltage surges. They can also be used as potentiometers with the division of voltage made independent of load current.

The resistors are composed of a silicon carbide ceramic resistance material called Thyrite whose non-linear resistance characteristic is stable and substantially independent of polarity and frequency. Its mechanical strength is 1,700 psi tensile, and 23,000 psi compressive. To avoid excessive oxidation of the metalized surface, and to prevent depreciation of the impregnating compound, the operating temperature of thyrite should not exceed 110 C continuously, nor 150 C for short times. The dielectric constant ranges from 30 to 100 or more, depending on the voltage and other factors.



The resistor line now includes small half-inch diameter units, with or without wire leads, having a maximum continuous rating in free air of 0.1 watt. Small one-quarter in., rod-type units, rated from 0.25 to 1.0 watt, are available from one inch up to six inches in length. For one watt ratings, rod-type resistors capable of continuous operation at 10 kf are available. Units are said to be suitable for electronic applications where space is limited.

General Electric Co., Schenectady 5, N. Y.

Tester Checks Load and Deflection of Springs

A new type of spring testing instrument, designed as an accurate, precision instrument for checking the loads and deflections of compression and extension springs, is used for general purpose or occasional checking, and also for high quantity production testing. Speed of production testing depends on type of spring and ability to place it in position and deflect handle. From 300 to 600 tests per hour have been made. Production stops can be set to test springs at an exact length, at a definite deflection or at a specified load.

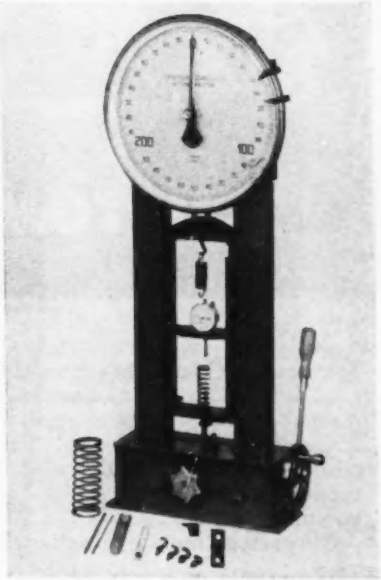
To operate the tester, place a compression spring on the lower platform or an extension spring on the hooks, rotate the handle and read the load on the dial. Spring lengths are indicated on two 12 in. steel rules, one for compression and one for extension springs. These are graduated in 32nds and 64ths on one side, and by reversing the rules, readings may be read in decimals in 10ths and 100ths of an inch. The movable platform in the center is moved up and down by the operation of the handwheel, compressing or extending a spring as desired. All testers are suitable for spring diameters up to 4 in., spring lengths of 12 in. for compression, and 10 in. for extension.

Spring lengths can be read accurately on the steel scales, and a dial indicator and brackets are available for reading to accuracies of 0.001 inch.

The testers are bench mounted, use standard gears and racks, standard bushings of bronze, and have a 5 in. dia handwheel for light springs up to 50 lb tests, and a 10 in. long handle for heavy springs up to 300 lb tests. Magnetic tolerance markers are spaced on the rim of the scale.

The 25 lb tester has a dial readable to 0.025 lb; the 100 lb tester is readable to 0.1 lb; the 200 lb to $\frac{1}{2}$ lb; and the 300 lb tester to $\frac{1}{4}$ pound.

The testers measure $14\frac{1}{2}$ in. wide, 5 in. deep, and 38 in. high.



Carlson Co., 277 Broadway, New York 7, N. Y.

CONTINUED ON PAGE 232

No better source of piping information ...than your handy CRANE catalog

Faced with a piping problem? Turn then to your handy Crane Catalog and see how quickly you find the answer.

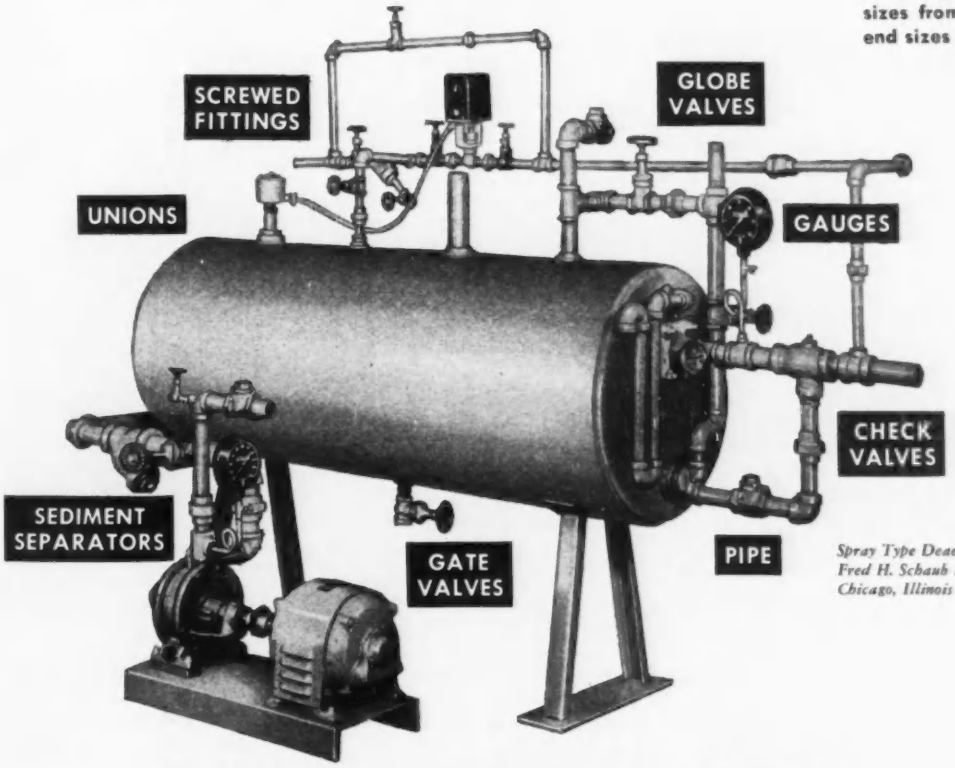
For within the 600 pages of this valuable book is full information on the world's most complete selection of quality piping materials—sizes and dimensions, tabulated pressure and temperature ratings, design, material and construction details, plus recommended applications. And it's all there indexed and arranged to save you time. In addition, you'll find an abundance of general engineering information.

Yes, specifying from your Crane Catalog is easier, quicker *and also safer* because you are specifying the finest piping available anywhere—piping that is recognized by machinery buyers for its dependable service and long range economy.

YOUR BEST BRASS CHECK

for hot and cold service in the 200-300 pound class—is this regrinding-type Swing Check Valve. Of simplified Y-Pattern design with a sturdy body of Crane Special Brass, it assures smooth flow with minimum resistance, and fast action in backflow. Easily reground without removing from line. Screwed end sizes from ¼ to 3-inch; Flanged end sizes from 1 to 3-inch.

NO BETTER SOURCE OF QUALITY ...THAN THE COMPLETE CRANE PIPING LINE



Spray Type Deaerating System by Fred H. Schaub Engineering Co., Chicago, Illinois

The Complete Crane Line Meets All Your Valve Needs. That's Why—
More Crane Valves Are Used Than Any Other Make!

CRANE VALVES

CRANE CO., *General Offices:* 836 S. Michigan Ave., Chicago 5, Illinois
Branches and Wholesalers Serving All Industrial Areas

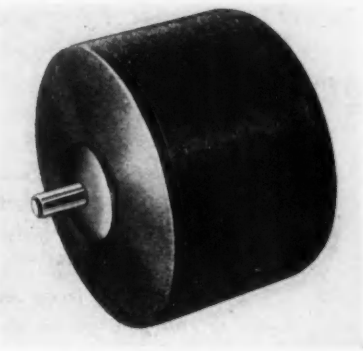
VALVES • FITTINGS • PIPE • PLUMBING • HEATING

Roto-Stepper With Complete Rotation in Both Directions

Shown in the illustration is a roto-stepper, a stepping positioner with sufficient torque to drive many low torque mechanisms. Features of unit include its ability to rotate in unlimited clockwise or counter-clockwise directions, its small size, and its adaptability to many applications. It is a solenoid-operated device normally rotating in 2 deg increments. Other increments are available.

Suitable for operating indicators, potentiometers, selsyns, synchros, switching devices and other low-torque mechanisms, it has a 24 volt system, longlife solenoids and can be ordered in the following combinations with or without shaft output: shaft output, shaft output with potentiometer output, shaft output with potentiometer output, and homing segments; shaft output with potentiometer output, homing segments and internal autocycling.

Other Specifications: Stepping Rate: responds to a maximum of 720 impulses per minute with min. pulse length of 0.05 secs, up to 30 pulses per second, depending on torque. Torque Output: varies with pulse rate approximately 12 in.-oz at 12 pulses per second Current: 0.6 amps max at rated voltage at 25 C. Torque Detent Spring: prevents reverse rotation of output shaft for torque not exceeding 1.5 oz-inches. Acceleration: meets specifications during ±6G steady state acceleration in 3 major axes for 15 minutes maximum. Vibration: meets specs during 0.020 in. double amplitude sinusoidal vibrations of 10 to 55 cps along the major axes for 15 minutes maximum.



G. M. Giannini Co., Pasadena, Calif.

All Purpose Submersible Centrifugal Pump

Model P-104, an all-purpose completely submersible centrifugal pump, has both the motor and pump enclosed in a compact, hermetically sealed case filled with oil, giving constant lubrication and eliminating periodic maintenance.

Measuring only 7¼ in. high, 4⅞ in. width min, and 5 13/16 in. width max, the pump has a maximum head of 9 feet. Maximum capacity at zero head is 1,000 gph; at a 3 ft head, 840 gph; at a 5 ft head, 660 gph; and at a 7 ft head, 435 gph. Watt input at a 3 ft head is 170; at the maximum of a 9 ft head, 140 watts.

Because the pump can be placed directly into the liquid without complicated connections, it is suited for many coolant applications, eliminating a pump-belt-motor combination.

Other features: heat dissipated from motor to oil to water; shaded pole type motor; low power consumption; no bearings or critical parts run in water; no stuffing box; as pump is submersible, no priming is necessary; open type impeller; hycar and neoprene parts; ceramic seat type seal operating against a stationary carbon seal member; and a vertical discharge.

Another submersible pump made by this company is the model P-109 sump pump in a cast iron waterproof case.

Kenco Inc., 1125 N. Ridge Rd., Lorain, Ohio

New 100 KC Small, Ferro-Resonant Flip-Flop

A new, model MC, 100 kc ferro-resonant flip-flop has been developed as a highly efficient replacement for the vacuum tube in certain counting, amplifying and control specifications. It has the durability, economy of power, and low heat dissipation of the saturable reactor, and at the same time is small, simple, and inexpensive.

It will operate on approximately 10 percent of the power needed by a vacuum tube, and can deliver more than 90 percent of the input energy as usable output, since copper and core loss cause the power consumption.

By using non-dissipating reactive elements, there is no problem of heat dissipation. The flip flop will not wear or burn out, can be mounted in any circuit, and is not affected by high acceleration and shock.

Specifications: A-C requirements: 1.6 megacycles, 1 w at 12 v rms; trigger input impedance, 5 millihenries in series with 25 ohms d-c resistance; trigger power requirements, pulse 8 to 16 v and 1 to 5 micro-seconds duration; output swing, the model MC has two outputs, opposite in phase, swinging between plus 3 and plus 21 volts. Outputs may be made to swing between minus 3 and minus 21 by reversing output rectifier diode; output power, the two outputs, opposite in phase, are capable of delivering 30 milliamps at 21 volts each; rated pulse frequency, 100,000 pulses per second.

Computer Research Corp., 3348 W. El Segundo Blvd., Hawthorne, Cal.

CONTINUED ON PAGE 234

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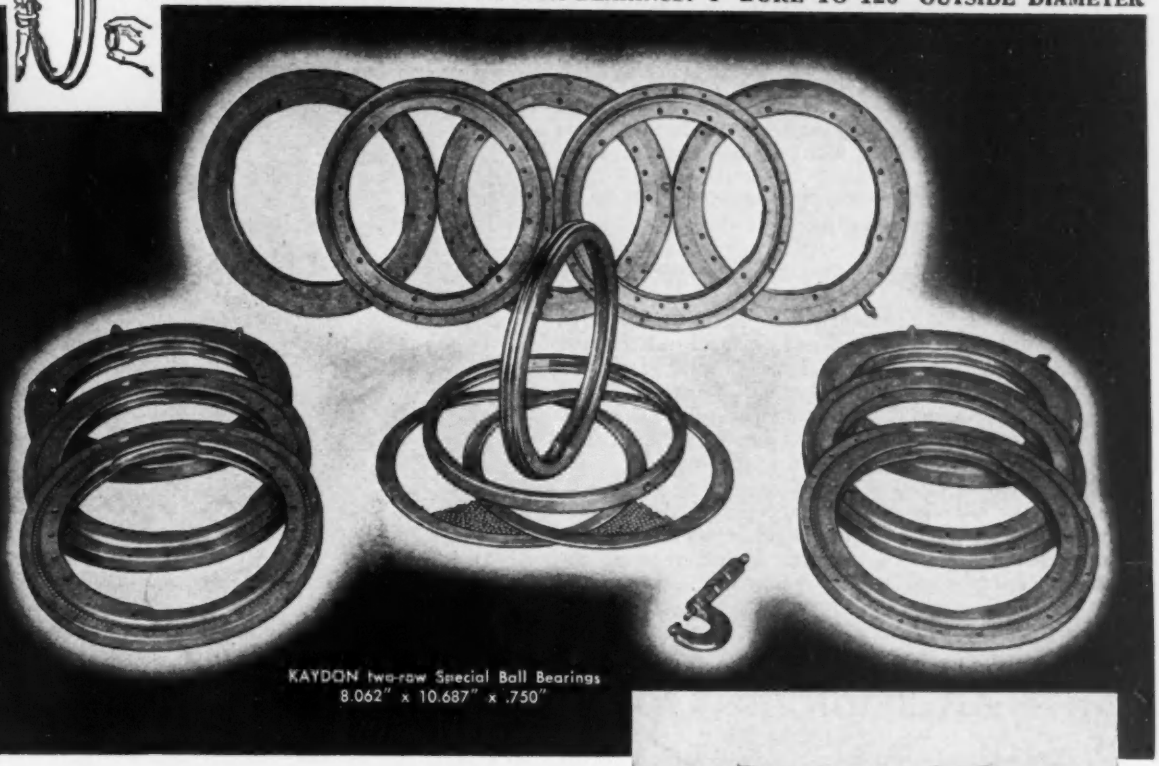
Contact KAYDON of Muskegon

FOR ALL TYPES OF BALL AND ROLLER BEARINGS: 4" BORE TO 120" OUTSIDE DIAMETER



KAYDON two-row Special Ball Bearings
8.062" x 10.687" x .750"

Dependable Life-Savers ...KAYDON-bearinged Piasecki HELICOPTERS

CONTROL movements of Piasecki HUP Helicopters . . . life-savers of the air . . . are transmitted to the spinning rotor blade assemblies by means of a swash plate that moves on unique two-row KAYDON Special Ball Bearings.

Control of the helicopter is obtained by the movement of its rotor blades. Each blade can move in six different directions while they are rotating. Thus the mechanism responsible for control movements is complex, important, and it demands the utmost in bearing-precision.

KAYDON met the challenge of this intricate bearing-problem with these special two-row, thin section, 8.062" x 10.687" x .750" ball bearings. Similarly, KAYDON cooperates with designers of many types of precision equipment to achieve their objectives.

KAYDON Types of Standard and Special Bearings:
Spherical Roller • Taper Roller • Ball Radial • Ball Thrust
• Roller Radial • Roller Thrust • Bi-Angular Bearings

THE KAYDON ENGINEERING CORP.

MUSKEGON • MICHIGAN

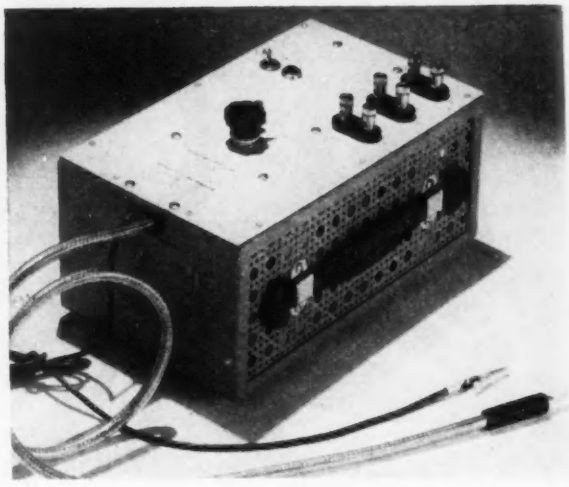
PRECISION BALL AND ROLLER BEARINGS

Speeds of Electrical Measurements Increased

Designed to increase the speed and accuracy of electrical measurements, the new model 102 phantom repeater features a circuit with a high input impedance at the ends of the test leads, coupled with an instrument amplifier having a low output impedance. The instrument's input impedance is now greater than 200 megohms shunted by 6.0 mmf, and output impedance is within 350 ohms in series with 8 mfd. Other features include gains of 1.0, 10, and 100; and frequency response of 5 cps to over 150,000 cps.

The entire input circuit of the repeater is enclosed in a shield which is driven at almost the same instantaneous potential as the test signal conductor. Therefore, the circuit being tested has to supply only a fraction of the usual charge, reducing the apparent capacitance. Also, only a fraction of the usual current flows through the conducting paths, increasing the apparent resistance.

In addition to increasing the sensitivity of almost any voltmeter or cathode ray oscilloscope, the repeater eliminates the many test leads often found. Only a single conductor has to be moved about the circuit, reducing the number of steps in a series of measurements.



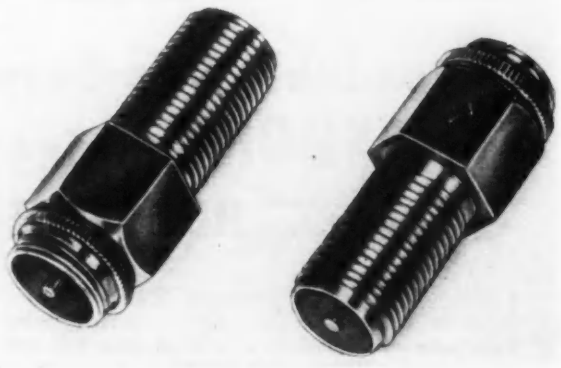
Keithley Instruments, 3868 Carnegie Ave., Cleveland 15, Ohio

Mechanically Operated Impulse Generator

This new model 3010 electro magnetic pick-up is an electrical impulse generating device that produces a voltage output proportional to the rate of motion or speed of the magnetic object, and operates without physical contact when mounted near any moving magnetic material. It may be actuated by the keyway in a shaft, the teeth of a gear, the spokes of a wheel, a slot in the rim of a wheel or shaft, a screw head or pin on a moving part, or any vibration or displacement of magnetic material in the field of the pick-up.

The pick-up may be used for measuring acceleration and velocity; triggering or synchronizing cathode ray oscillograph sweep circuits; angular position indicator (shaft or fly-wheel); or reference marker (degrees, position). It will indicate rpm, count operations, sequences, cycles or motion at rates in excess of 20,000 per second when used with electronic counters.

Specifications: The device has an output in excess of 2 v peak to peak, depending upon spacing, speed of moving part and displacement amplitude; it will respond to mechanical movements at rates in excess of 20,000 per second; it has an AISI 416 stainless steel body; an amphenol type 80C1 connectior; overall length 2 in.; diameter $\frac{5}{8}$ in.—18 threads/in. (NF or SAE); weight less than 2 ounces. More information may be obtained from the manufacturer.



Electro Products Labs, Inc., 4501 N. Ravenswood Ave., Chicago 40, Ill.

A TIMED DELAY RELAY, adjustable from 0.10 to one second, uses a rock-shaft motion instead of thermal or shorted turn principles. The new rock shaft motion is unaffected by heat, cold, vibration, or impact. Other features; time interval independent of voltage; instantaneous reset; snap acting contacts; rating, 3 amp, non-inductive 28 v d-c; 1½ amp inductive 115 v a-c. Cook Electric Co., 2700 N. Southport Ave., Chicago 14, Ill.

DEVELOPMENT OF STYROPHANE, a new organic coating for polystyrene, designed to withstand high humidity, may be used as a decorative coating for refrigerators and household appliances. It may be applied by spray to injection molded polystyrene parts. It has good wetting characteristics and good flow or leveling out. Standard-Toch Chemicals, Inc., 2600 Richmond Terrace, Staten Island 3, N. Y.

CONTINUED ON PAGE 236

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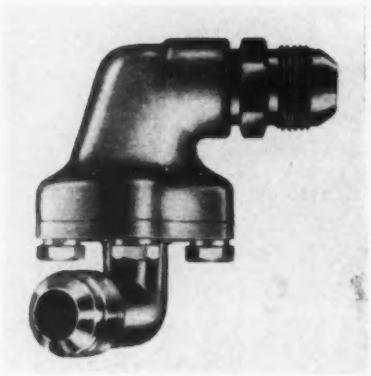
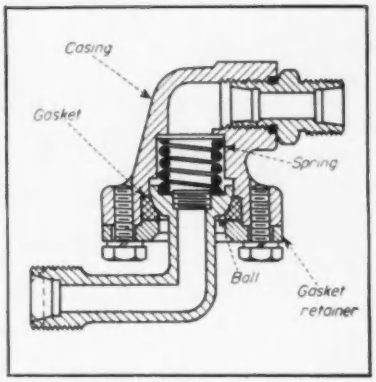
High Pressure Hydraulic Swivel Joint

A complete standardized line of high pressure hydraulic swivel joints for general industrial, military, and aircraft use with tubing or pipe has a selfaligning feature that is said to simplify and speed up installation, and minimize wear. The joint has a side flexing feature that permits movement in any direction, and absorbing all vibration. Also, there is no metal-to-metal contact between moving parts since the ball seats in a chemically inert gasket as shown.





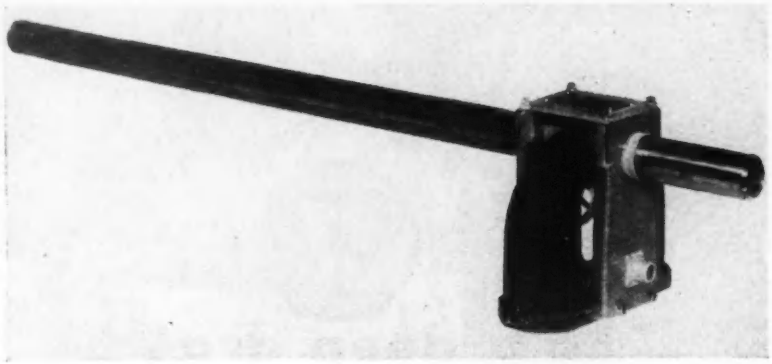
The joints are produced in four different styles with straight or angle conections for use with $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, or $\frac{5}{8}$ in. tubing, or equivalent size pipe. All styles and sizes are available with a choice of thread connections: AN, industrial ermeto, or standard pipe threads. Pressure ratings are 3,000 psi hydraulic with steel or aluminum casing and stainless steel ball. Depending on the operating service conditions, temperatures ranging from −100 to +500 F can be handled.

Principal uses for swivel joints of this type are in high pressure hydraulic circuits where flexible blowout-proof all-metal lines are wanted. The joints give a 360 deg swivel action and have up to 15 deg side flexibility. In other types of service, the joints may be used for handling air, steam, refrigerants, lubricants, or chemicals at high pressures and temperatures.

Barco Mfg. Co., 1801 Winnemac Ave., Chicago 40, Ill.

Remote Measurement of Molten Metal Flow

A new device, called a magnetic flowmeter, for the remote measurement of molten-metal flow, has been designed so that its sensing element is external to the flowing liquid. This gives protection where metals such as sodium, lead-bismuth, and sodium potassium alloys, must be metered.



According to the manufacturers, one of the basic features of the flowmeter is that it eliminates all movable parts and physical obstructions to fluid flow. It consists essentially of a permanent magnet with a pipe centered between the magnet pole faces by means of stainless-steel supports.

As the molten metal flows through the pipe, it cuts the magnetic lines of flux set up by the magnet. This generates a small directional voltage in the pipe proportional to the amount of magnetic flux and the rate of metal flow. The voltage is picked up off the pipe by two stainless-steel wires and transmitted to an instrument showing the prevailing flow rate or a recording meter providing a permanent record of flow rates.

It is possible to use any potentiometer-type indicating or recording instrument for the measurement of the millivolt output of the flowmeter.

The sensing head of the new device is 3 x 5¼ x 6 in. and will measure flow in pipe sizes of ½, ¾, or 1 inch. Accuracy of the magnetic flowmeter is plus or minus three percent.

General Electric Co., Schenectady 5, N. Y.

MOLDED IN MOISTURE-RESISTANT, non-flammable thermosetting plastic, rated at 20,000 v d-c, and designed for 85 C operation, a new type 700 C high-voltage ceramic capacitors will find use as high-voltage supply filters in television receivers and cathode-ray instruments. Standard rated capacitance is 500 mmf. The capacitors withstand a dielectric test potential of 30,000 volts. Minimum insulation resistance under standard test procedures at 25 C is 10,000 megohms. Sprague Electric Co., 195 Marshall St., North Adams, Mass.

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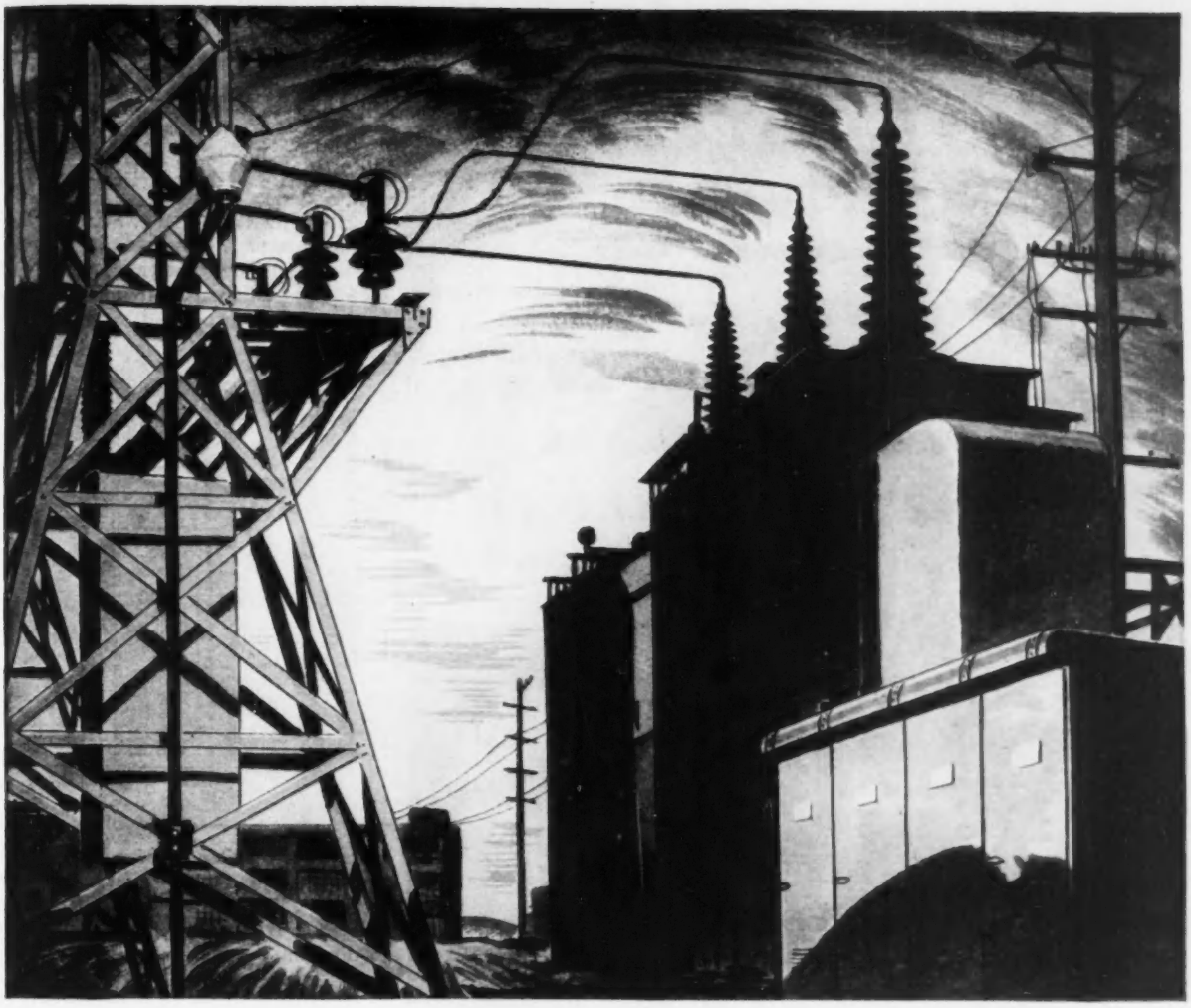

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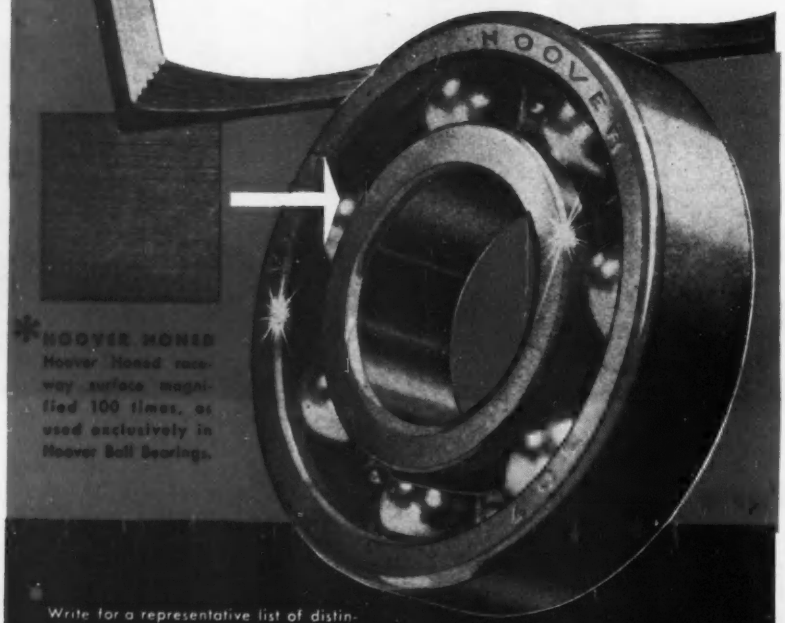

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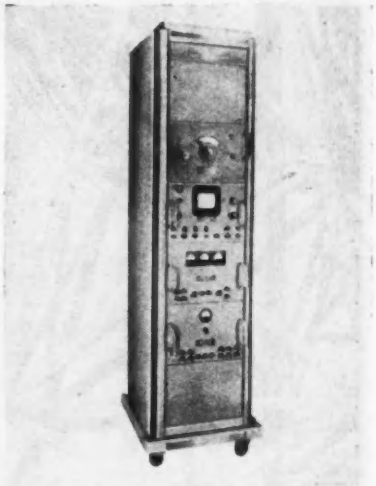
All Band Direct Reading Spectrum Analyzer

A new and improved all band direct reading spectrum analyzer, covering the frequency range from 10 mc to 21,000 mc, is covered by means of four tuning units. It has continuous unidial tuning over the entire range with 5 kc resolution at all frequencies. The frequency can be read to an accuracy



of 1 percent, and dispersion is independent of frequency and available from 250 kc to 25 mc. A frequency marker is used to measure frequency differences from 0 to 25 mc.

The microwave tuning units use the latest design non-conducting shorts to insure accurate resettability and long mechanical life.

Polarad Electronics Corp.,
100 *Metropolitan Ave., Brooklyn* 11, *N. Y.*

Solenoid Shut-Off Valve With Time Delay

Manufacturers of electro-magnetic controls have recently designed a midget solenoid shut-off valve with a time delay mechanism which holds back the flow of liquid or gas through the valve for about 5½ sec. after the solenoid becomes energized. This feature is said to make the valve useful in oil burner applications where it is necessary to have instant combustion. The time delay mechanism holds back the flow of oil until a full stream of air, sufficient to make a perfect combustible mix, is flowing through the burner. On subsequent stoppage and re-lighting, the delay gives enough time to purge the fire box of old fumes and smoke. The valve can be installed in any position without affecting the time delay action. Shut-off is instanta-

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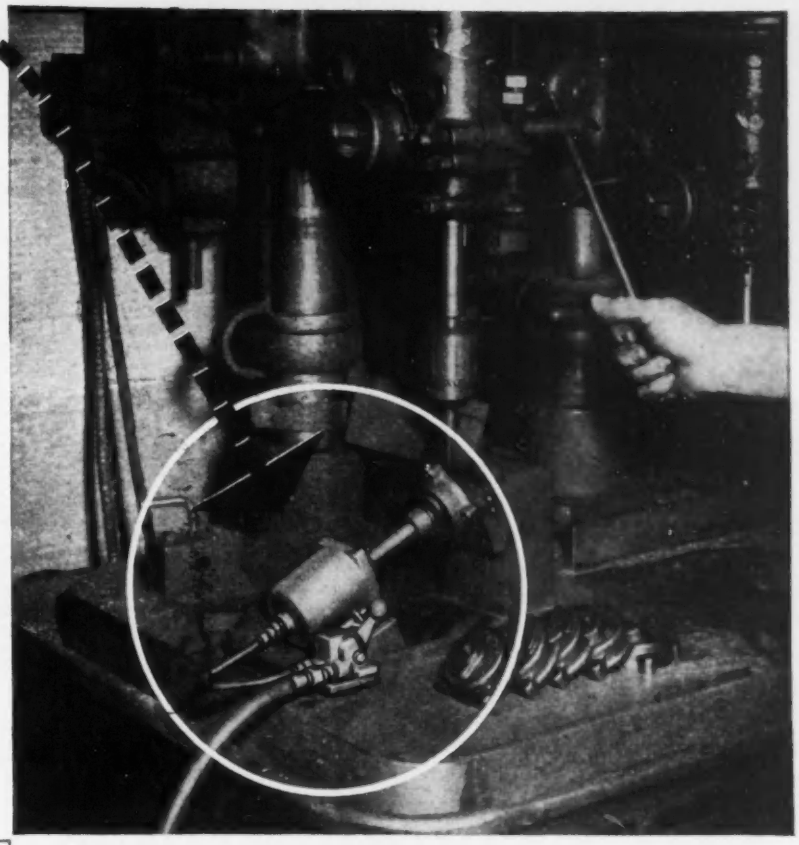
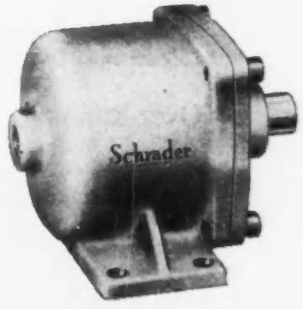
Simplify any work-holding problem





ClampAir Cylinder

Watch a worker making ready for a simple drilling operation. He places the work in a fixture and hand-clamps it. With everything all set to go, you'll find he takes as much as ten seconds just to grip the work tightly in the clamp.

Multiply that by thousands of machining operations in a normal high production shop. You'll find a substantial portion of work time is used up before actual production is begun.

You can eliminate nearly all of this lost time with the new Schrader ClampAir. What's more, since the ClampAir takes no more effort than opening a valve, high-priced workers are not tired by useless labor.

The ClampAir is actually a bantam air cylinder, with plenty of power to hold work firmly in place—with the same holding force every time. That means the end of rejects caused by inconsistent holding forces.

The number of places where ClampAir can serve you well is on drill presses, milling machines, gluing operations, and others too numerous to mention. In all of these, production rates can be upped to higher percentage brackets with ClampAir. And, since ClampAir is basically a push type cylinder, it can be used in many other spots where you need a short, hard stroke.

It's easy to find out how ClampAir can shorten production time, increase worker efficiency. Write, outlining the applications in which you are interested—or fill out the coupon below. We will be glad to help you determine your needs.

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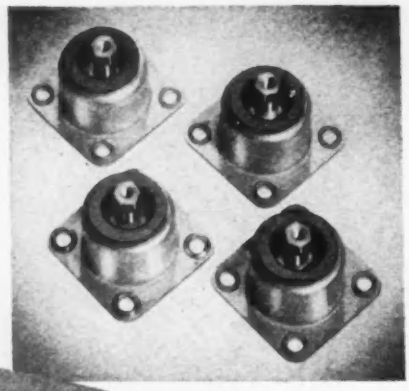
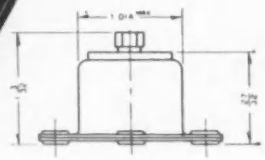


Photo courtesy Vapor Heating Corp.



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2. Less weight — only 5/16 ounce per unit isolator.
3. Wide load range — 0.1 to 3.0 pounds per isolator.
4. Satisfy temperature (−67 to +170F), vibration, and other performance requirements of JAN-C-172A — special models available for extreme high or low temperatures.
5. Ruggedized models — available for equipment that must meet shock-test requirements of AN-E-19, MIL-E-5272, and MIL-T-5422.
6. Four styles — available as unit isolators or assembled with mounting bases built to your needs.

TYPE 6475

TYPE 6693

TYPE 6465

TYPE 6690

For complete information, ask for Barry Catalog 523-A; it's free on request. And for greatest benefits with miniature Barrymounts, let our Field Engineering Service share our experience with you in the early stages of your designs.

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neous and positive. Overall size, top to bottom, is 2 13/16 inches. A similar 3 way valve with time delay feature is available.

This time delay feature also permits the valve to be used for machine and instrument control where a timed delay in flow is desirable after the coil is energized.

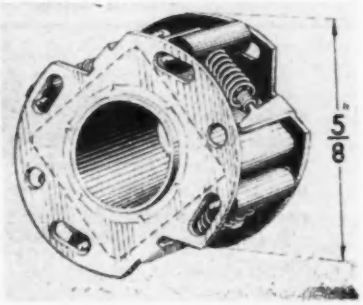
The valve has $\frac{1}{8}$-in. pipe connection and full $\frac{1}{16}$ in. port for pressures up to 150 lb with 15 gal per hr flow. Also available is a similar valve with a $\frac{1}{8}$ in. pipe connection, a full $\frac{1}{4}$ in. port for pressures up to 125 lb, 40 gal per hr flow, and a time delay of approximately $6\frac{1}{2}$ seconds. Standard continuous duty coil for 115 v, 60 cycles. Brass or stainless steel body with stainless steel operating parts, and a soft composition disk to give tight shutoff.

Automatic Switch Co.,
379-D Lakeside Ave., Orange, N. J.

Smallest Over-Running Clutch

A line of miniature over-running clutches, said to be the smallest commercially available, and known as Miniclutch has such applications as: recording instruments and business machines, motion picture projectors, sewing machines, automatic vending machines, ratchet-feeds, servo mechanisms, lubricant pumps, and control devices like those used in gun-pointing equipment.

This one-way miniature clutch has four rollers, features quick, smooth action, and stands up under long and



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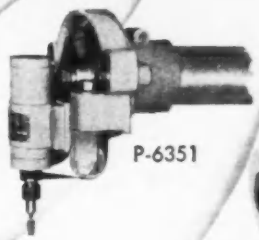
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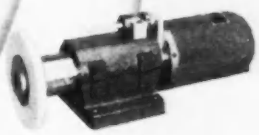
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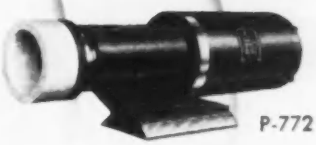
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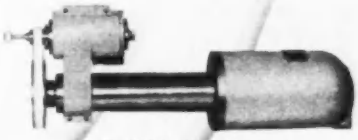
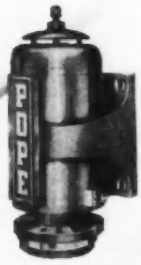

P-6271 Attachment



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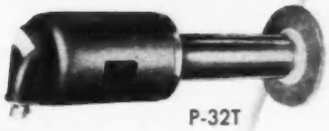
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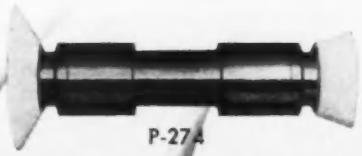
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continuous use. Tests on a unit measuring ¾ in. in diameter used as a variable stroke ratchet showed the ability to throttle down to a feed of less than 1/300th of a revolution per stroke.

Other features are: infinitely adjustable ratchet feed; automatic coupling mechanism; selective coupling; dual or multiple drives; and free wheeling of high inertia parts.

High Precision, Inc.,
375 Morse St., Hamden, Conn.

Automatic Power Steering

A fully automatic, compressed air-operated power steer booster gives easier, safe steering of trucks, tractors, moto-cranes, off-the-road and heavy road construction equipment, military, and other specialized vehicles, and can be adjusted by operator at instrument panel to give desired amount of steering assist for any load, condition of road, speed or any combination of these variables. The unit uses compressed air for its power, and requires few fittings for installation on old or

new vehicles without altering or removing any part of the steering mechanism. One end of booster is fastened to a stationary member of vehicle. The other end of the accessory is attached to a movable part of the steering linkage, pitman arm, drag link, or tie rod. Only one air line is needed. The device requires no oiling, and can't jam or freeze. There are no reservoirs to fill, no pumps to replace, and no fluid to leak away.

The Air-O-Matic Power Steer Corp.,
24 Noble Court, N.W., Cleveland 13, Ohio

Fastening Device for Switch Assemblies

A fastening device that is said to simplify switch assemblies and solve the problem of attaching plastic push buttons to switch arms may be used on all types of push button switches used with household appliances, electrical controls and lighting equipment.

Installed without use of special tools, the new fastening is a small stamping ⅜ in. long and ¼ in. wide. It has a down turned section that overlaps the end of the switch arm; a bent tab slips into a prepared hole at a fixed distance from the switch arm and two prongs project upward to bite

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ARALDITE® BONDING RESINS

ARALDITE® TYPE	CURING CONDITIONS	PHYSICAL APPEARANCE	BOND STRENGTH* ALUMINUM-ALUMINUM (LB./SQ. IN.)	SUGGESTED USE
AN-101	Room temperature	High viscosity liquid	2000-2500	Bonds or seals glass-metal.
AN-102	Room temperature	Low viscosity liquid contains solvents	1400-1600	Bonds metal-metal and metal-wood.
AN-111	Heat cure	Low viscosity liquid contains solvents	2000-2500	Impregnating (vacuum method), laminating and bonding.
AN-115	Heat cure	Low viscosity liquid contains solvents	2500-3000	Impregnating, laminating and bonding.
AN-106	Heat cure	Heavy paste silver color	3000-3200	Bonds socket-type joint.
AN-107	Heat cure	Heavy paste tan color	3000-3200	Bonds socket-type joint.
AN-112	Heat cure	Heavy paste tan color	2500-3000	Laminating, bonding. Rapid cure.
AN-100	Heat cure	Powder tan color	4000-4500	Bonds Heat-resistant, smooth, non-porous materials . . . metal-metal, metal-glass, metal-ceramic, glass-glass
AN-110	Heat cure	Powder silver color	4000-4500	
AN-120	Heat cure	Stick tan color	4000-4500	
AN-130	Heat cure	Stick silver color	4000-4500	
AN-104	Room temperature	Non-flowing paste tan color	1000-1500	Bonds loose-fitting joints.
AN-103	Heat cure	Non-flowing paste tan color	1200-1400	Bonds loose-fitting joints.

*ASTM D1002-49T

ARALDITE® CASTING RESINS

ARALDITE® TYPE	CURE	PHYSICAL APPEARANCE	SUGGESTED USE	SHRINKAGE	ELECTRICAL PROPERTIES
CN-501	Heat cure	Amber solid	Casting, potting, encapsulating. Good adhesion.	Very low (½ to 2%)	Excellent
CN-502	Room temperature or heat cure	Thin liquid	Casting, potting, encapsulating. Good adhesion.	Very low (½ to 2%)	Good
CN-503	Room temperature or heat cure	Liquid	Similar to Araldite CN-501. Low temperature. Pour.	Very low (½ to 2%)	Excellent
CN-504	Heat cure	Very thin liquid	Impregnating, casting, potting, encapsulating. Good adhesion.	Low (< 2%)	Good

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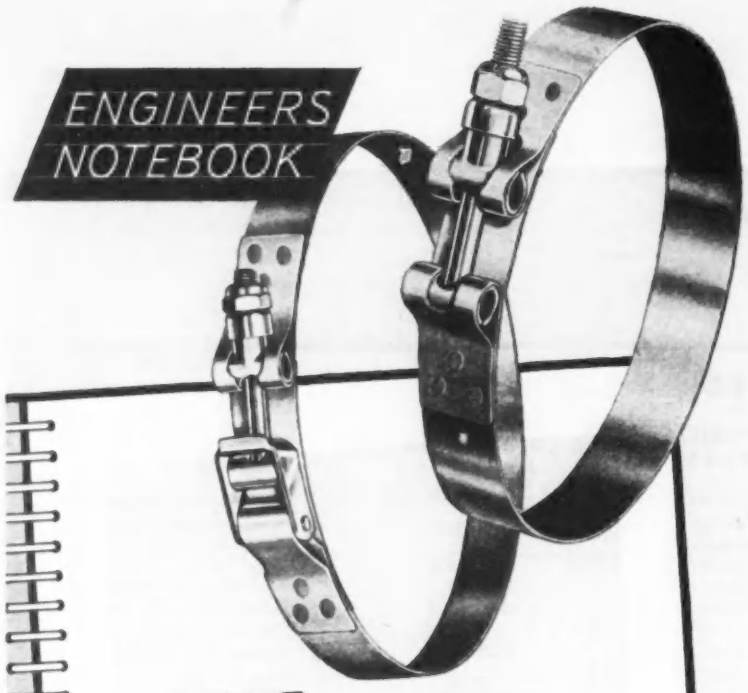
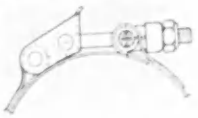


Marman

STANDARD BAND CLAMPS
FAST DELIVERY—
FAST PRODUCTION

New plant facilities and methods at Marman have lowered delivery time on standard band clamps to two weeks. This is but one of many advantages brought about by Marman's standardization of clamps for applications which heretofore required special designs. Today they are used throughout industry for all types of hose and duct connections, attachment of accessories, securing of wiring and miscellaneous equipment.



The Quick Coupler type with patented latch is particularly useful where ease and speed of assembly are important.

The T-Bolt which provides even circumferential tension finds ideal application where high strength and an especially tight seal are required.

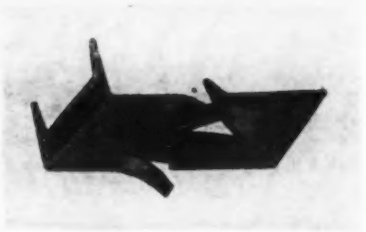
Simple, foolproof design, light weight and ease of installation have led to the specification of Marman Clamps on virtually all U.S. aircraft.

FOR ADDITIONAL INFORMATION
WRITE FOR ENGINEERS' NOTEBOOK #21 E

MARMAN PRODUCTS CO., Inc.
11214 EXPOSITION BLVD.
LOS ANGELES 64, CALIF.

SAVE COST TIME AND WEIGHT WITH MARMAN

STANDARD CLAMPS FOR SPECIAL APPLICATIONS



into the plastic push button. As the push button is slipped over the switch arm with the mounting clip in place, the projecting prongs are compressed. Once the button is in place, the prongs engage the inner surface of the button, locking it in place.

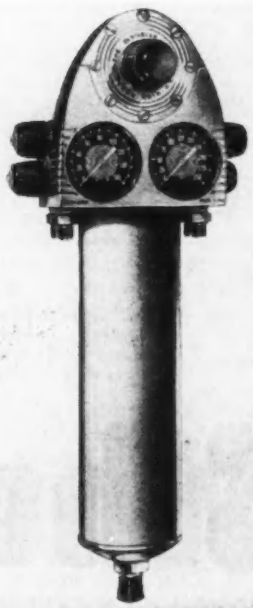
The clip is designed to engage even the hard, brittle plastics sometimes used where high insulating characteristics are required, and will fit any size or thickness of switch arm, providing only that the prepared hole in the arm is correctly placed with respect to the end of the arm.

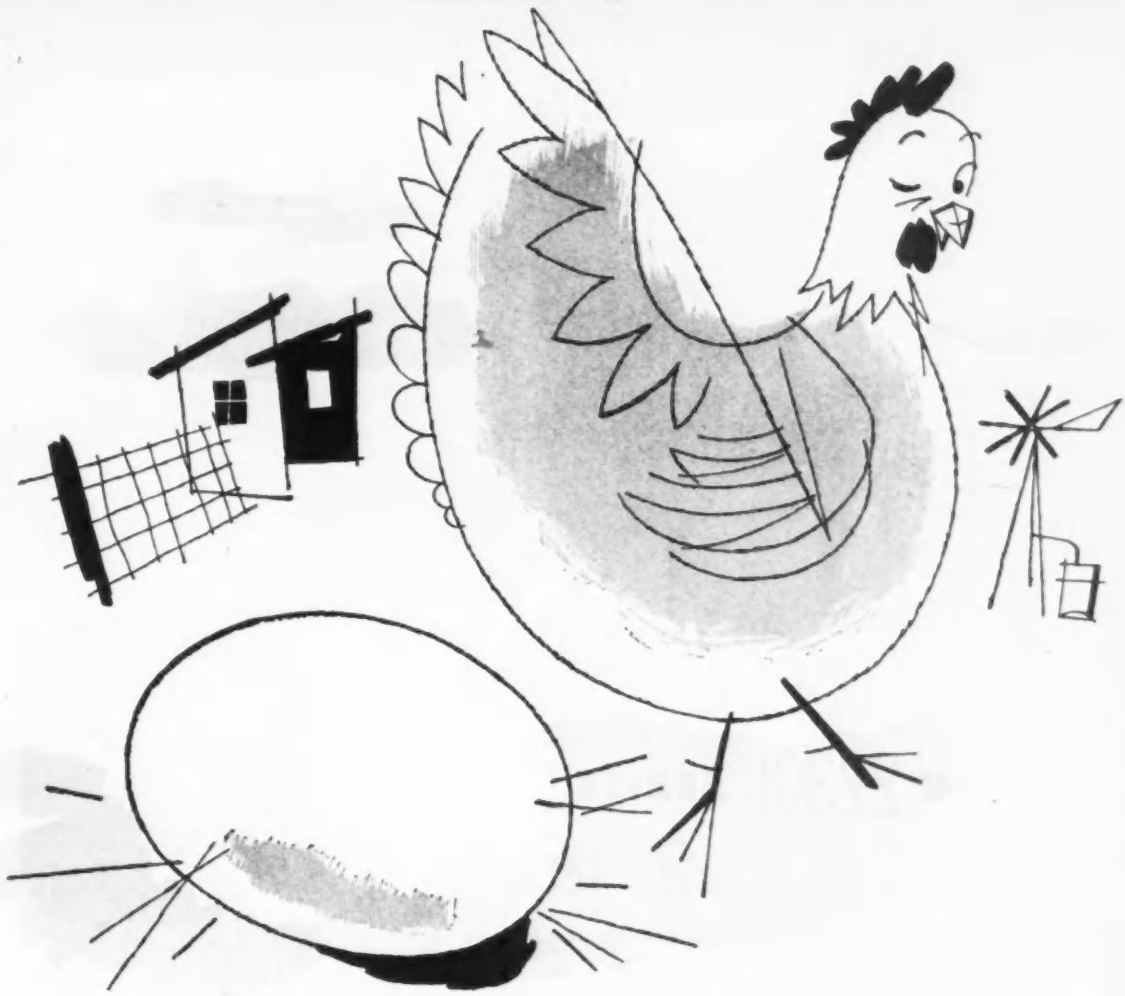
Shakeproof, Inc.,
St. Charles Rd., Elgin, Ill.

Large Capacity Air Transformer

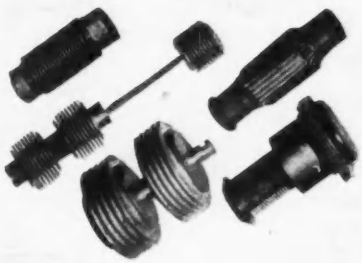
Said to be more efficient, easier operating, and having a greater capacity than former types, the new HLD air transformer has a built-in stage regulating principle for easier adjustment of pressures. The knob actuates a small pilot regulator which in turn operates the diaphragm of the large regulator. In tests, 97 percent of entrained water was removed from 100 cfm of air at 100 lb pressure.

The transformer has two regulated





IT TAKES A SPECIALIST to do the job!



THAT'S WHY so many manufacturers come to Fulton Sylphon or Bridgeport Thermostat for bellows assemblies. For building them is a specialty with us—has been for half-a-century.

We have the skilled personnel—the background experience—the production facilities to build bellows assemblies exactly suited to your needs. And our specialized experience can save you time and money—because we can take over the complete job, relieve you of all production problems and worries.

We design and engineer bellows assemblies that are used throughout industry—as flexible connectors . . . for thermostatic devices . . . pressure controls . . . hydraulic mechanisms . . . valves . . . shaft seals . . . recording instruments and for other uses. Wide range of sizes. Stainless steel and other metals.

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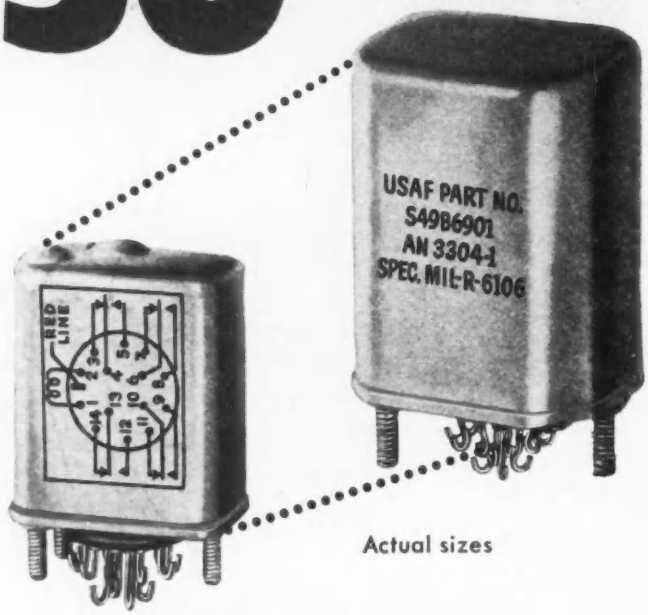


Actual sizes

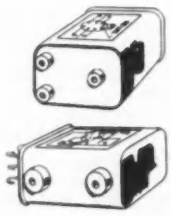
R-B-M 22300 SERIES

Hermetically Sealed Relays

The R-B-M 22300 hermetically sealed telephone type relay is the electrical and mechanical equivalent of AN 3304-1, except for smaller size and mounting dimensions.

An improved armature design, plus high temperature molded nylon coil bobbin, provides greatly improved magnetic efficiency and enables R-B-M to reduce the overall size of the relay. The R-B-M 22300 design still retains palladium cross-bar contacts identical to those used in the larger size.

Maximum contacts—6 Form A and 4 Form C-3 ampere 28 Volts. D. C. coil construction only. Maximum coil resistance 5000 ohms. Minimum power .75 watts. Also available in AN 3304 can for dynamotor or low capacitance application.



Optional Mounting Arrangements

Write Dept. C-10 for ASR Bulletin.

RBM

R-B-M DIVISION
ESSEX WIRE CORP.
Logansport, Indiana

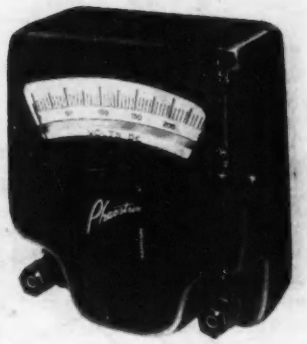
MANUAL AND MAGNETIC ELECTRIC CONTROLS
—FOR AUTOMOTIVE, INDUSTRIAL, COMMUNICATION AND ELECTRONIC USE

air outlets and two unregulated, and has a capacity of 100 cfm. The head of the transformer housing the regulator, two pressure gages and valves, is a zinc die casting. The separating mechanism is a mechanical disk type filter.

The DeVilbiss Co., 296 Phillips Ave., Toledo 1, Ohio

Meter Has Five Scale Ranges

A new laboratory type instrument, ruggedized for field service and available as a d-c voltmeter, a-c voltmeter, and d-c milliammeter, features 5 full scale ranges, a range and scale changer which automatically changes meter electrical characteristics to correspond



to the selected scale, a mirrow scale for laboratory precision, 3-way binding posts, and a military type movement. The selected scale only is visible, eliminating reading errors of the multi-scale instrument.

These instruments are available singly and in sets of four, and make possible simultaneous measurement of 2 or more circuit characteristics.

Phaostron Co., 151 Pasadena Ave., South Pasadena, Calif.

Precision High Temperature Resistors

A complete line of precision resistors specifically designed for high temperature applications are said to operate with dependability and long life where ambient temperatures in excess of 235 C are encountered. In addition they feature a low temperature coefficient resulting in nearly constant ohmic value over a range from —55 C to +125 C. The total percentage change in resistance is under 0.2 percent.

These resistors are small, compact

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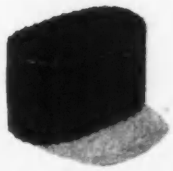
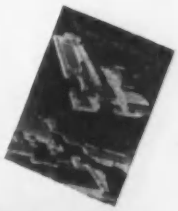
RUBBER PARTS FABRICATED BY STALWART



ONLY SILICONE RUBBER PARTS can withstand temperatures ranging from +500° to -110° F. Because of their extraordinary properties, silicone parts have excellent resistance to weathering, oxidation, moisture, ozone, permanent compression set, and many chemicals and oils.

SILICONE PARTS FABRICATED BY STALWART assure maximum performance and maintain their desirable physical, chemical and dielectric properties under critical operating conditions. In many applications, they have replaced metal fabrications forced upon manufacturers by the limited thermal stability of organic rubbers. Silicone rubber parts now are used for many difficult applications . . . aircraft seals and instruments, marine equipment, transformers, internal combustion engines, motors, generators, chemical and electronic equipment, etc.

EXPERIENCED STALWART ENGINEERS are prepared to mold, extrude, punch, machine-cut and mandrel-build precision silicone rubber parts to meet individual as well as S.A.E. and A.S.T.M. specifications.



Write today for CATALOG 51SR-1 for additional information.

812-SR

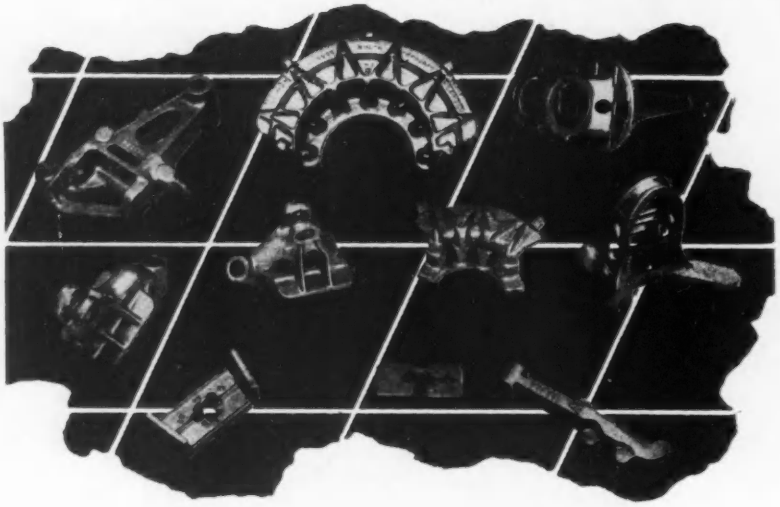
STALWART RUBBER COMPANY

200 NORTHFIELD ROAD • BEDFORD, OHIO

UNITCAST

Daily rides the AIRLANES

(Aircraft castings used directly or as an accessory attachment)



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..ENGINEERED TO "TAKE IT"

Each of the above castings is the result of cooperative designs embodying the best-known foundry techniques available to assure the production of HIGH STRENGTH, MINIMUM WEIGHT, DEFECT-FREE castings. Each part is either percentage checked or 100% checked by radiographic and magnetic particle inspection.

Unitcast HAS met and WILL continue to meet the demands of industry, producing pre-determined TOP QUALITY castings, as shipped, and with personal follow-up to check machinability, fixture fit, assembly fit, etc., in YOUR PLANT.

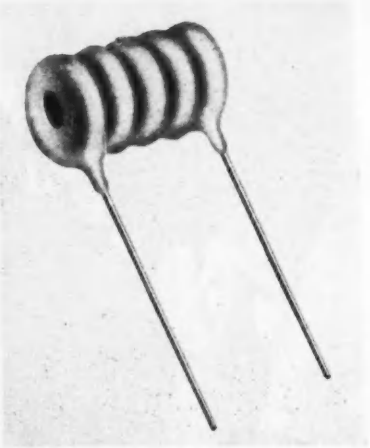
Your successes reflect on our books. May we offer our services to challenge any knotty problem your product may present to the castings industry.

UNITCAST Corporation

QUALITY STEEL CASTINGS

Give us a chance to offer a "cast steel" answer for your parts problem. Our suggestions while your product is in the design stage will pay continuous dividends.
Write or call today. Unitcast Corporation, Steel Casting Division, Toledo 9, Ohio. In Canada: Canadian-Unitcast Steel, Ltd., Sherbrooke, Quebec.

UNITCASTINGS ARE FOUNDRY ENGINEERED



and are available in four types. Maximum resistances to 25,000 ohms and power ratings to 6 w can be supplied. Standard tolerances are 1 percent, special to 0.1 percent.

Instrument Resistors Co., Commerce Ave., Union, N. J.

ACCURATE MEASUREMENT of flow of liquids and gas under difficult conditions is made possible by the development of a new, improved flowmeter. The unit is capable of handling toxic or highly corrosive substances, viscous liquids or other fluids under pressures up to 20,000 psi, and temperatures ranging from —269 C to 1,200 F. One of the sensing elements is as small as 3/16 in. in dia, and in aluminum only 2½ ounces in weight. The largest element measures six inches and permits accuracy of flow control up to 4,000 gallons per minute. Minneapolis-Honeywell Regulator Co., 4494 Wayne Ave., Philadelphia 44, Pa.

A SYNTHETIC RUBBER COMPOUND for use with synthetic lubricants at high temperature has been developed to meet specification MIL-R-7362. Called compound 56243, it can be furnished in molded and extruded shapes, lathe-cut, washer and die-cut parts. The compound is said to perform equally well for sealing greases, meeting specification MIL-G-3278, (formerly AN-G-25). Western Felt Works, 4035-4117 Ogden Ave., Chicago 23, Ill.

A POWER REGULATING UNIT will convert 115 v a-c to 6 v d-c, adjustable ± 10 percent, at currents of 5, 15, 40 and 100 amp with a regulation accuracy of ± 0.2 percent. A new feature is a front panel switch that instantly changes the output from 6 to 7 v a-c, adjustable ± 10 percent. Sorensen & Co., Inc., 375 Fairfield Ave., Stamford, Conn.

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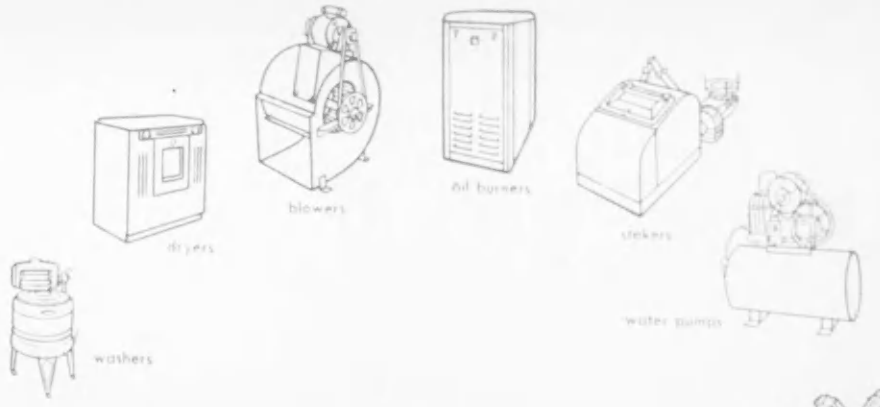

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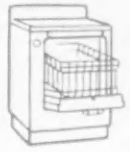
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ventilating units

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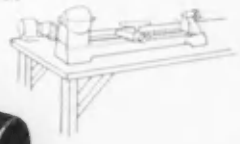
bench tools

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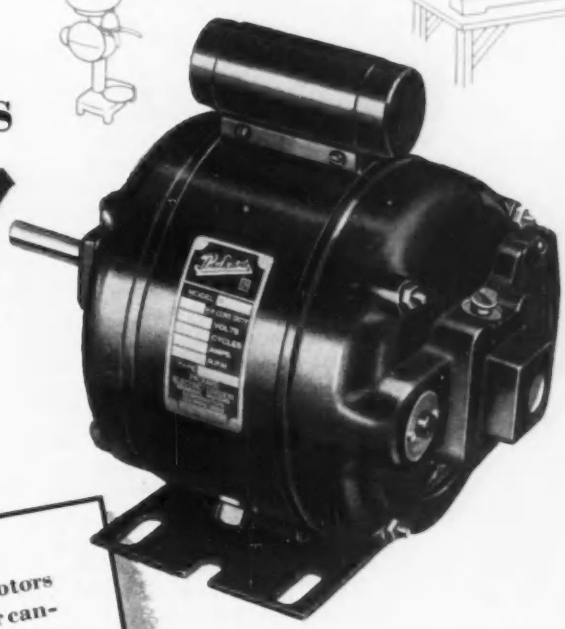

Packard fractional horsepower motors offer advantages that the careful buyer can-not afford to overlook. There's a 35-year success story behind each Packard motor.

Packard

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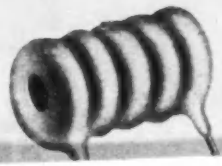
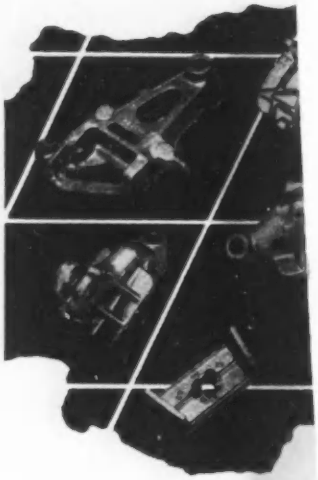
GM GENERAL MOTORS

Packard Electric Division, General Motors Corporation
Warren, Ohio

DEPENDABLE APPLIANCE MOTORS FOR THIRTY-FIVE YEARS

UNITCAST
Daily rides the AIRLANES
(Aircraft castings used directly or as an accessory attachment)





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available to assure the
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feature is a front panel switch that instantly changes the output from 6 to 7 v a-c, adjustable ± 10 percent. Sorensen & Co., Inc., 375 Fairfield Ave., Stamford, Conn.

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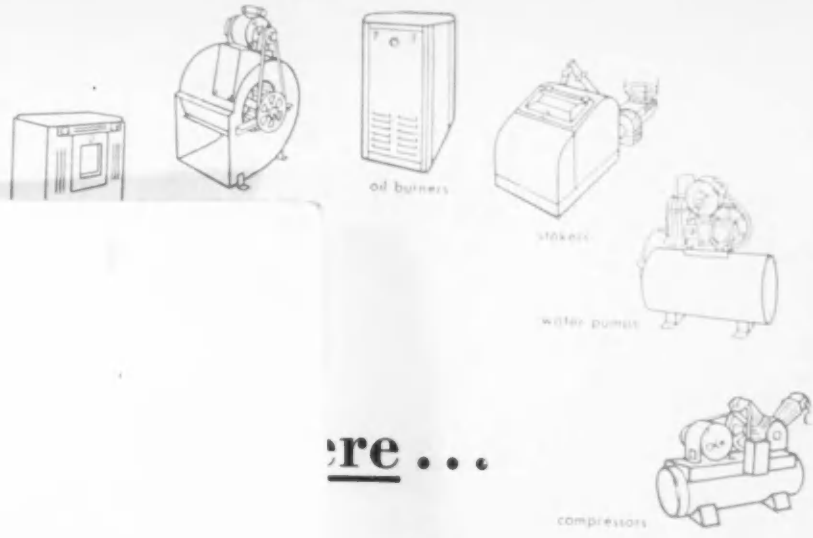

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compressors

ventilating units

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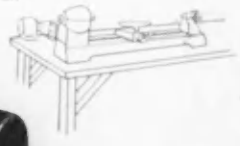
orators



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Packard

GM GENERAL MOTORS

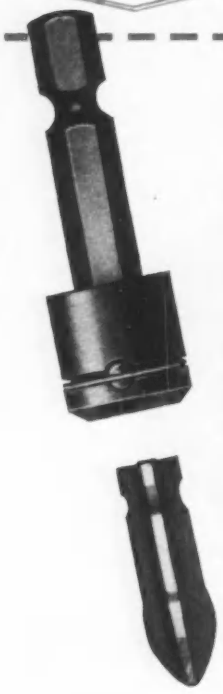
Packard Electric Division, General Motors Corporation
Warren, Ohio

DEPENDABLE APPLIANCE MOTORS FOR THIRTY-FIVE YEARS

PARK-O-METER

discovers

HY-PRO PHILLIPS INSERT BITS



The Macnick Division of the Rockwell Register Corporation makes this famous "Nickel Grabber" in Tulsa, Oklahoma.

Before Macnick discovered and started to use Hy-Pro Phillips Insert Bits for their glass-mounting operation in the assembly department of the Park-O-Meter case, they had screw-driving troubles. Their Phillips Tools lasted only seven or ten days and drove only 60,000 recessed head screws before they had to be taken off the assembly line and resharpened.

Now, with the Continental Screw Company's New Hy-Pro Phillips Insert Bits, Park-O-Meter drives approximately 420,000 screws. And, the Hy-Pro Phillips Insert Bits last from seven to eight weeks before replacement is necessary.

This kind of a production story is fairly typical of those who use Continental products and methods. When it takes place on your production line, it can mean more money in your own pocket and worth-while savings for your company all along the line.

Call Continental when you have an unusual screw fastening problem and see what you can save . . . in money . . . manpower . . . methods or materials. Continental Screw Company, New Bedford, Mass.

—You can count on Continental ©

Sans, Souci

Ad Libbing by the Editor

Reasoning based on circumstantial evidence may often be illogical if all of the facts were not known. The red hairs in the hat left behind by the criminal does not prove that the criminal is a red head. He may be a blonde or brunette man who swiped a red head's hat. A ball-bearing was taken out of its housing, in good condition except that the outer surface of the outer race had a bluish tinge. The shop man claimed that the race had rotated in its housing and turned partially blue from the heat of friction. Actually the fellow who installed the bearing had some Prussian blue on his fingers. The fellow didn't wash his hands before putting in the bearing.

People in general, including engineers, will often waste hours of precious time "discussing" some problem or other. The fact may be that they are not discussing anything because they are just guessing. If I have to guess I'd rather go to the horse races and do my guessing there. It would probably cost me a lot of money, but I would not be listening to a lot of windy conversation by people who are guessing at the basic facts.

The vice-president in charge of engineering called a meeting to decide what to do about a certain rivet failure. The question was whether outside consultants should be brought in to make a thorough stress analysis or whether a test program should be set up. Soon the whole discussion got off the track. The chief engineer was certain that the failure was caused by heating effects. The quality control head ventured that a change from coke fire to electric rivet heating was the cause. The production manager opined that the extremely low temperature on the day the rivets were driven must have had an effect.

All during this conjecture period one of the project engineers sat without saying a word. Finally the veep asked if he had anything to suggest. His answer was, "Those rivets have less than one tenth percent carbon, so there could not have been any heat treating effects. Also, I saw the same thing happen with cold driven rivets, so I am sure the heating had nothing to do with the failure, and I have no guess to offer."

A deadly silence ensued. The phrase, "I have no guess to offer," had hit the nail on the head. The

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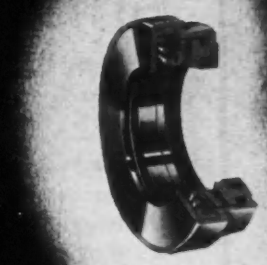
Now STANDARDIZED



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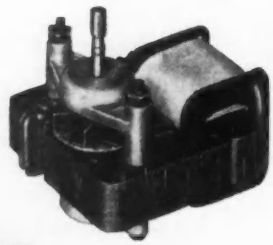
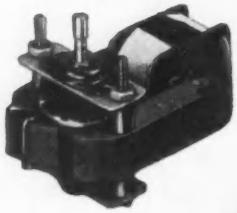
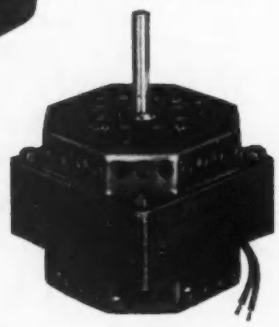
- Record changers
- Kitchen exhaust fans
- Small unit heaters
- Timing devices
- Window ventilators



MODEL A
2-pole induction type



MODEL C
2-pole induction type



MODEL D
4-pole induction type

THE GENERAL INDUSTRIES CO.
DEPARTMENT MM • ELYRIA, OHIO

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vice-president assigned one of the engineers to undertake an investigation to find the cause and the meeting was adjourned. All that could have been done without a meeting. But humans do love meetings to talk and listen to others talking.

Just now we are nationally in the midst of hearing a lot of speeches. The candidates for the office of president are sure busy criticizing the other fellow, promising wonderful things that they will do if elected, dishing out a lot of generalities and tactfully avoiding statements that will lose votes. I never have taken much stock in election promises and assurances. I guide myself by actual performance. If the gang in power is doing a good honest job I vote for its re-election. If the gang in office has been pulling a lot of shenanigans, collecting graft, condoning crookedness, coddling tax evaders, stealing the publics' money and using the power of their office to prevent the prosecution of the guilty ones, I say it should be overwhelmingly voted out of office.

Too bad that this is a technical magazine and not a newspaper. If it were the latter we could announce our support of one of the candidates. As it is we must "stick to our knitting." I must not tell our readers that I am in spiritual agreement with the newspapers that have announced their support of General Eisenhower. In other words, I refuse to put my stamp of approval on crookedness in public office regardless of the promises made by the candidates of the party in power to reform if elected. Their gang had its chance, proved itself crooked, now even confess it, so out it must go.

It is amazing how many dumb, docile and gullible humans there are. At least 60 percent of the world's population falls in that class, that being the percentage of the world's population that is living in Asia and Russia. We ought to include the population of all the iron-curtain countries and most of Africa, but we want to be conservative.

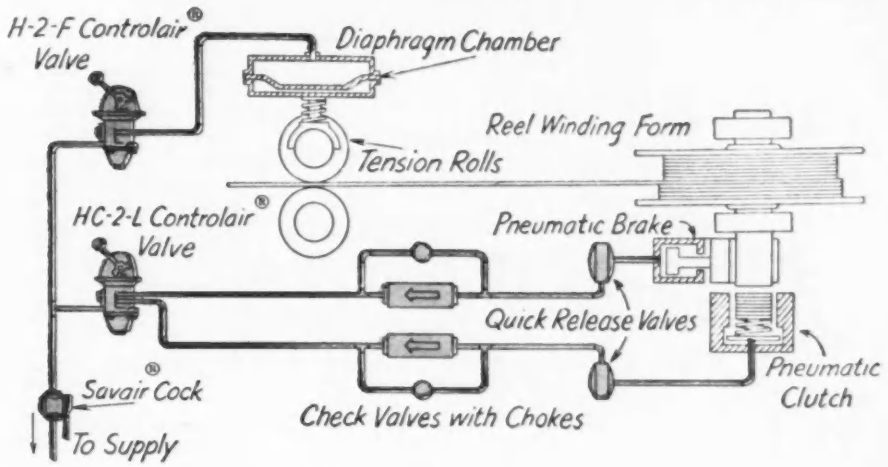
We can now apply this scientific figure, so expertly arrived at, to any section of the human race, any geographical area, any activity, or any product. It is a wow of an advertising tool. For example, "all but 40 percent of the cigarette smokers smoke Sine Puffs. Significantly, this figure is the scientifically established 40 percent of dumb, docile and gullible humans. Be smart. Smoke Sine Puffs."

Silly? Of course it is! It is almost as silly as much of our consumer goods advertising.

—G. F. N.

Pneumatic controls cut labor costs

and provide automatic operation of wire drawing machinery



AN Eastern steel wire manufacturer needed a control system that would enable just one man—instead of two—to operate his wire drawing and windup machinery. Tension on wire forming rolls had to be closely controlled to maintain wire size. The control system had to prevent the operator from applying the brake and clutch simultaneously and from applying either one too fast.

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ENGINEERING ABSTRACTS

Ultrasonics . . . Inspection Applications Grow

Abstracted from "Ultrasonics . . . Inspection Applications Grow" by Ralph H. Frank, Sperry Products, Inc., Danbury, Conn. *Steel*, June 16, 1952.

APPLICATION OF ULTRASONICS to inspection and measuring problems is growing as understanding of sound behavior in materials improves. Sound is now widely used to investigate internal flaws in castings or forgings and to determine thickness of metals with corroded inside surfaces or baked by liquids.

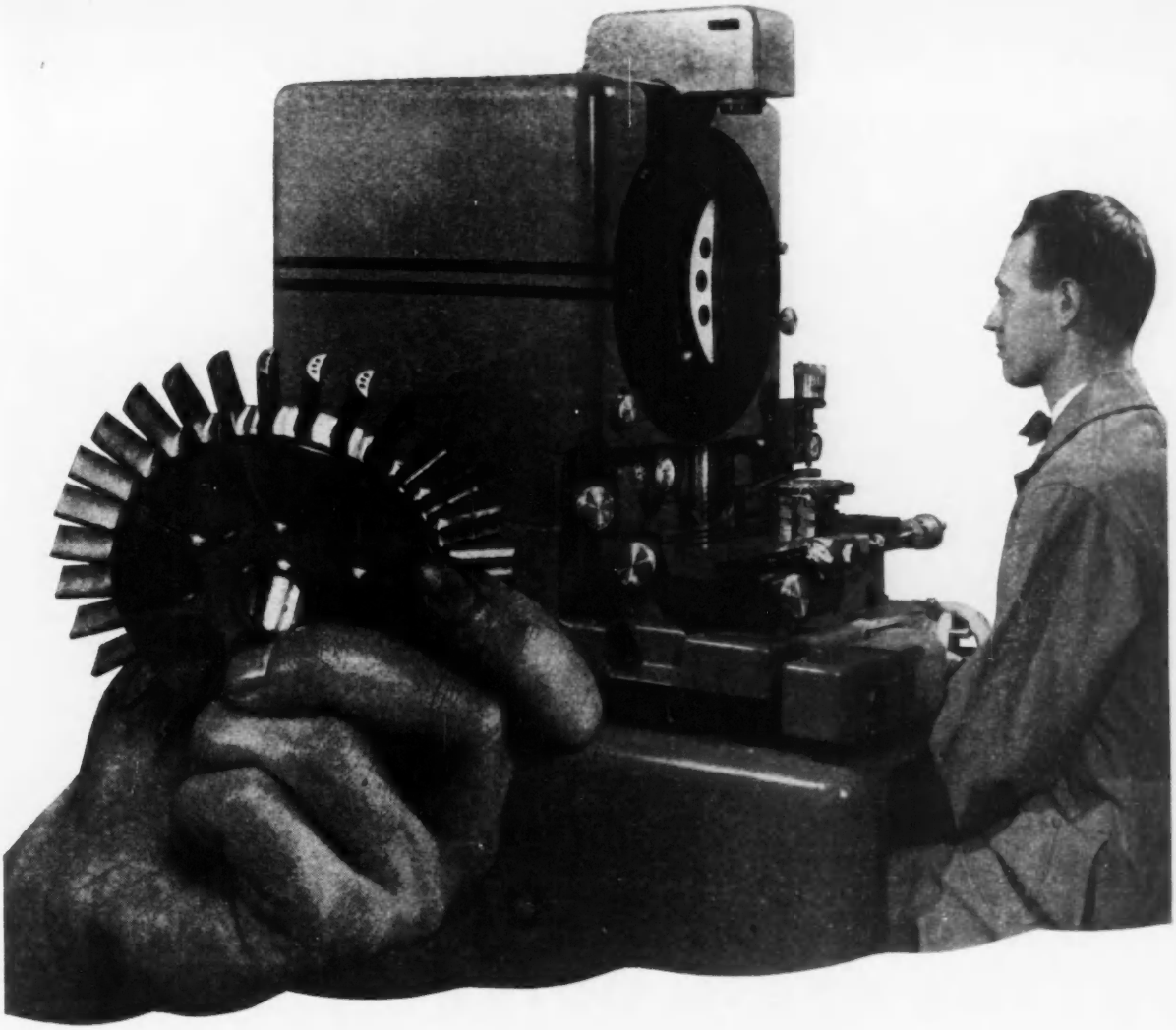
Heart of an ultrasonic system is the method of transforming electrical pulses into mechanical vibrations, and transforming the mechanical vibration back into electrical pulses. This phenomena is called piezoelectric; most common substance used for this purpose is quartz.

If an electrical field is applied across a piece of quartz its thickness will vary as the frequency of the applied field. Conversely, if the pressure is exerted on the face of the quartz, it will generate a small voltage of the same frequency as the applied vibration. The assembly holding the quartz is called a "transducer", and commonly referred to as a "searching-unit."

Acceleration Without Motion—Actual movement of quartz-vibration is infinitesimal; it is often described as acceleration without motion. To transmit such a small amount of energy into a material, it is necessary to use an incompressible couplant between the quartz face and the material surface. Oil is most commonly used for this purpose.

Test References Set Up—For practical use and acceptance of any nondestructive testing method, standards must be established. Most plants using ultrasonic testing have developed internal plant standards for their own use and reference, and recently through a committee of ASTM, work has been started on developing industry standards. Reference blocks with various diameter flat-bottom holes from $\frac{1}{64}$-in. to $\frac{1}{4}$-in. diameter are being considered.

In using such reference blocks, two methods of interpretation can be made. Most common method is to



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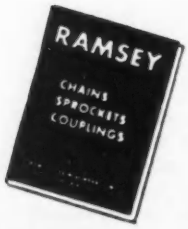

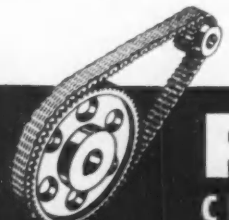

SILENT CHAIN DRIVES — FLEXIBLE COUPLINGS

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tune the Reflectoscope so the indication from the test hole gives a specified height. In testing, indications are evaluated as less than or greater than the reference indication height.

The other method of interpreting is to compare the height of the indication to the height of the back-reflection, and express this as a percentage of the back-reflection. This method has the distinct advantage that size, shape and surface conditions do not vary the relationship.

In the standardization program, test frequencies are also being suggested and adopted. For example, in the tool-

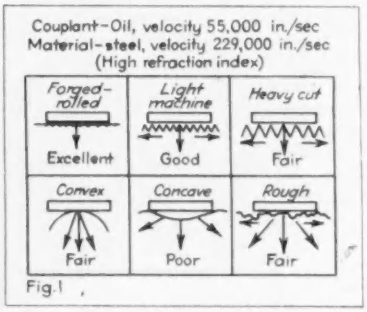

FIG. 1—Six tyypyical surfaces encountered in ultrasonic testing processes.

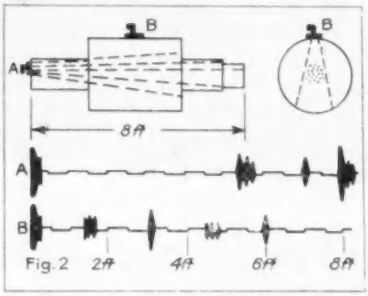

FIG. 2—Sound patterns with the searching unit placed in positions A and B.

steel, aircraft and forging industries, a test frequency of 2¼ megacycles is the accepted and used frequency. In the foundry industry, frequencies of 1 and 1½ megacycles are considered standard.

Forged Rotor Tested—In testing a large forging or casting such as in Fig. 2, when the searching unit is placed in position "A", the sound pattern shown below would result. The sound travels through the piece, and reflects off the shoulders as well as the end. With each marker set for 6 inches, distances to all shoulders and the end can be measured, confirming that the sound has penetrated the roll to the end with no abnormal indications. The operator is generally looking for transverse cracks.

Testing along the outside diameter

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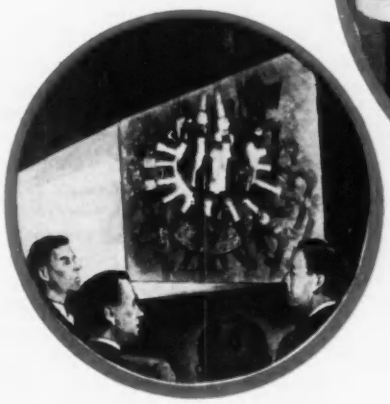

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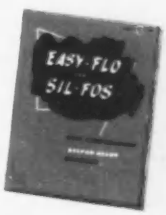

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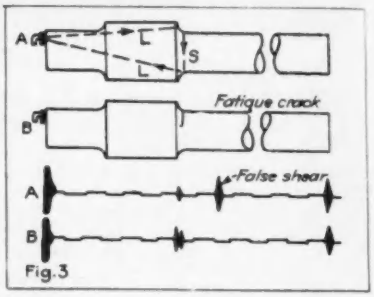

FIG. 3—In this crane shaft, direct sound path is to the opposite end.

surface as in position "B", the center area would be examined for longitudinal cracks, voids, pipe, etc. If the forging contained center porosity, our sound pattern would show the extent and area of such porosity as in B.

Maintenance Testing—A typical maintenance application is to test installed shafting, press columns, crankshafts, and other highly stressed parts subject to fatigue action. Such applications require both experience and judgment, or enough similar pieces that comparison tests can be made.

In testing a crane shaft, as in Fig. 3, the direct sound path is to the opposite end; a back-reflection should be obtained in a good shaft. Some of the sound would reflect back direct from the fillet, and would give a small indication at the correct fillet distance. The sound, however, that struck the fillet at 29 degrees would be converted into shear, cross the shaft at 90 degrees can be converted back into longitudinal sound and then be returned to the searching unit.

This sound path is shown in "A", and it's affect on the sound pattern shown below. A false indication would appear at a distance equal the diameter of the shaft in back of the fillet.

In testing of any pieces with fillets or tapers, the possibility of a false shear reflection must always be investigated before condemning the piece. A quick method of confirming or disproving such an indication is to test from the opposite end. Distance measurements will always confirm an actual crack at a specific location, but distance measurements from both ends will never jibe with false shear indications.

If a fatigue crack occurs in the fillet as in "B", it can readily be identified and its depth plotted on the end of the shaft.

End Reflections—Another interesting phenomena occurs in the end tests of pieces of long length compared to thickness. Instead of a single back-reflection, two or more equally spaced reflections are likely to appear. The

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sound paths causing these extra reflections are shown, and since the sound crosses the thickness at a constant angle and a constant velocity, the spacing of these end reflections is a measure of the thickness of the piece.

In steel, the thickness of the piece is equal to the spacing between any two reflections divided by a constant of 0.76. In aluminum the constant is 0.90.

In all cases the stray sound paths, wave conversions, etc., must occur after the direct reflection, since such paths are longer, and in the case of wave transformations, velocities are much slower. It is a good general rule to consider only the distance to the first end-reflection in interpretation and ignore in most cases the miscellaneous reflections that may follow.

Thickness Measurements — Two methods of measuring thickness with ultrasonics are commercially available. Each has certain advantages and limitations. The method based on resonance is particularly applicable in thickness ranges of 0.025 to 0.300-in. and where surfaces are not corroded or immersed.

Reflection technique in measuring thickness is illustrated in Fig. 4. A 5 megacycle searching unit is best to use, because of its short pulse and better definition. Using a reference piece 1 in. thick, and of the same material to be measured, the Reflectoscope is calibrated by marking the spacing of successive reflections on the oscilloscope tube, or by accurately setting the markers for ½-in. increments. Appearance of the scope would be as shown in "A" of Fig. 4.

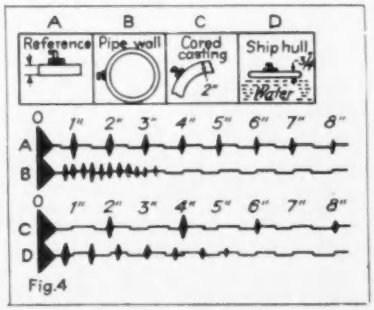

FIG. 4—Reflection technique for measuring the thickness of a part.

Suppose the thickness of the reference piece were reduced by $\frac{1}{32}$-in. The first reflection would shift to the left by $\frac{1}{32}$ in.; second reflection would multiply the difference in thickness, and the eighth reflection would occur on scale at $7\frac{3}{4}$-inches, instead of 8 inches. The slight shift which occurred at the first reflection could not be discerned

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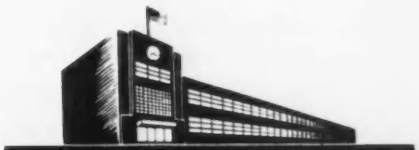

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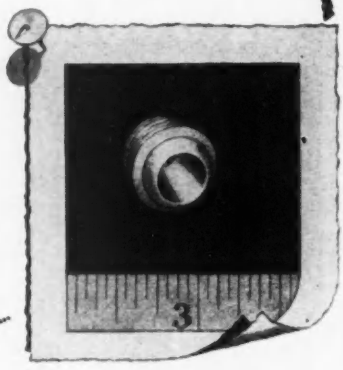

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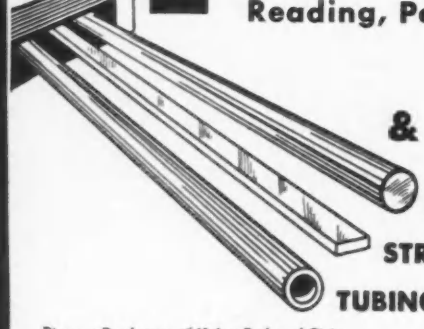

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or measured, but the ¼-in shift which resulted at the eighth reflection can be easily read and measured. The rule then for taking accurate thickness measurements is to read the length of multiple thicknesses, and divide by the number of multiples.

Count the Multiples—In measuring a ¼-in. pipe wall, it would be difficult to count the number of multiples, since some would be obscured in the pulse. In such a case, count the number of multiples in one inch, which would give a direct thickness reading.

In measuring a casting such as a tank turret for core shift, if the third reflection occurs at 6 inches, the wall thickness is 2 inches. If the third reflection occurs 6½ inches, the wall thickness is 2⅙ inches.

Thickness measurements with the Reflectoscope are not extremely accurate, but the advantage of being able to measure metals with corroded inside surfaces, and metals backed by liquids makes this method in many cases the only possible way to obtain thickness measurements.

Angle Testing—Another general application and method of ultrasonic testing is the use of shear waves introduced from the surface of the material at an approximate angle of 45 degrees. A quartz crystal mounted on a Lucite wedge of about 36 degrees, is assembled in a suitable holder. Refraction causes the sound to enter the steel at approximately 45 degrees, and at this angle, 90 percent of the incident energy is converted into shear waves. Due to the slow velocity of shear waves, their wavelength is proportionately shorter.

Testing at 1 megacycle with an angle search-unit, is approximately equivalent in sensitivity to testing with a 2¼ megacycle standard search-unit. Fig. 5 illustrates the testing technique and typical sound patters in the testing of plate and weldments.

Testing of Pipe & Tubing—Angle testing is also coming into general use in the testing of pipe and tubing. Sketches in Fig. 6 indicate the sound

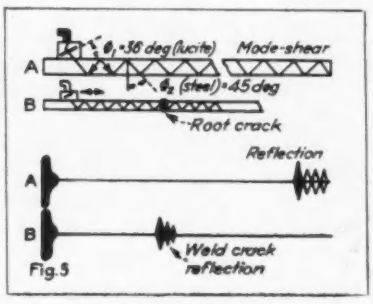
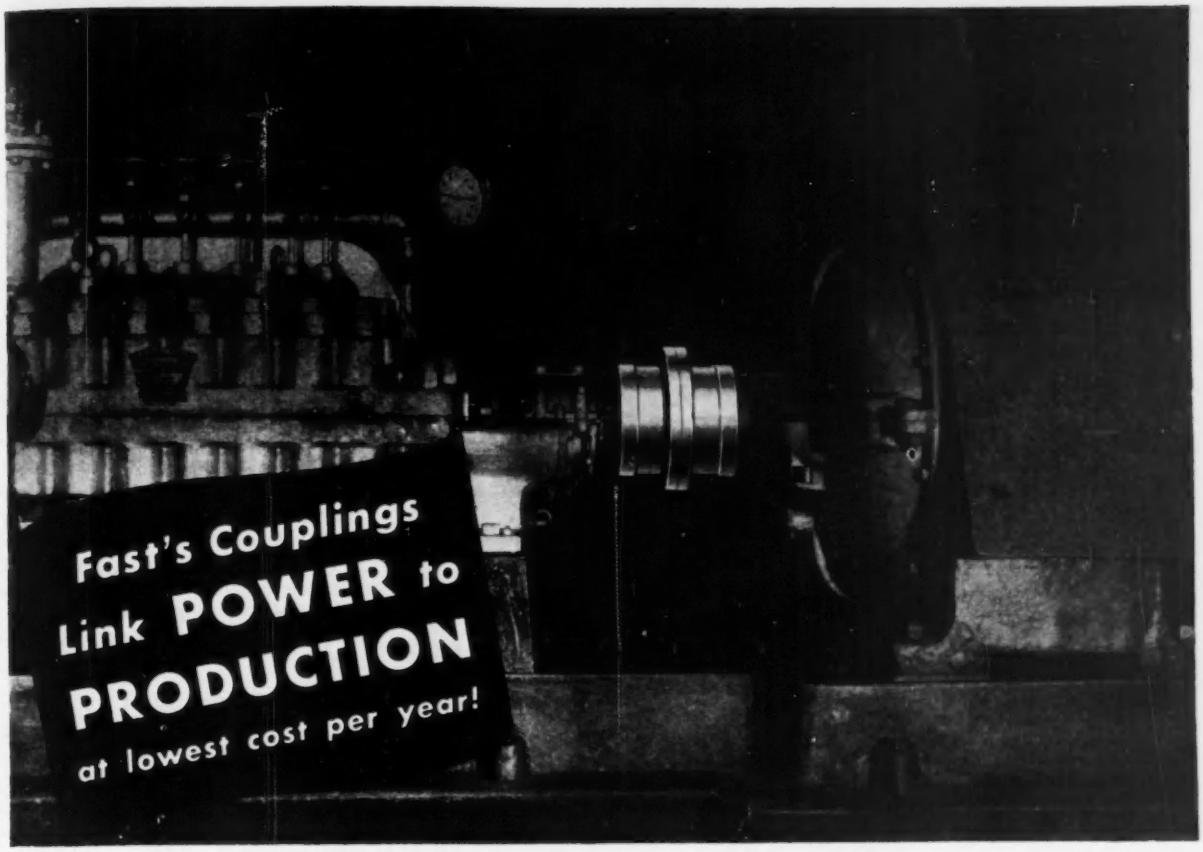


FIG. 5—Testing method and sound patterns for testing plate and weldments.



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Free Service—Koppers free engineering service assures you the right coupling for the job.

Rugged Construction—Fast's still maintains its original design, without basic change or sacrifice in size or materials. Result: freedom from expensive coupling failures.

Lowest Cost per Year—Fast's Couplings usually outlast equipment they connect. Their cost may be spread over many years!

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THE ORIGINAL
GEAR-TYPE
Couplings

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330 Scott St., Baltimore 3, Md.

Gentlemen: Send me Fast's Catalog which gives detailed descriptions, engineering drawings, capacity tables and photographs.

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or measured, but the ¼-in shift which resulted at the eighth reflection can be easily read and measured. The rule then for taking accurate thickness measurements is to read the length of multiple thicknesses, and divide by the number of multiples

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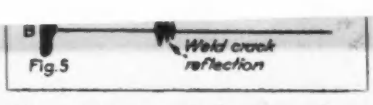

FIG. 5—Testing method and sound patterns for testing plate and weldments.

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Where start-and-stop cycles are toughest, you'll find Star Brakemotors on the job, hour after hour, day after day!

The extra-large braking area of Star-Kimble Brakemotors assures quick *stopping*, positive *holding* of the load—gives long service life with little maintenance. Small air gap between electromagnets and brake disc results in extremely fast *release*—allows motor to start smoothly, without friction drag. *Other features:*

Brake discs mounted close to motor for low wear and strain on shaft and bearings. Magnets mounted away from motor for cool operation. Quick, simple adjustment of braking torque. Automatic re-set hand release—an exclusive, patented Star-Kimble feature.

Remember . . . a Star-Kimble Brakemotor is a compact, integral unit—motor and brake *built* together to *work* together. Each Star-Kimble Brakemotor is designed for specific service requirements—by the company that pioneered disc brakemotors and has applied them successfully, for more than 25 years.

Want to know how Star-Kimble Brakemotors work—what torque and motor ratings are available? Write for free Bulletin B-501-A.

STAR-KIMBLE

MOTOR DIVISION OF
MIEHLE PRINTING PRESS & MANUFACTURING CO.
211 Bloomfield Avenue Bloomfield, New Jersey

on the casting technique employed, on the composition and properties of the material cast, and finally whether the casting has been submitted to a stress relief treatment.

To a great extent, the seriousness of the stresses can be minimized by proper design, proper casting technique, and the use of a material with a balance between strength and shrinkage without recourse to stress relief. The low shrinkage and wide strength range of gray iron, are advantageous in minimizing internal stresses. Also in certain of the softer gray iron grades, slight plastic flow at stresses under the elastic limit help prevent these stresses reaching critical levels. Residual stresses in castings seriously lower efficiency, and it is not sufficiently recognized that, even in the case of gray iron, the relief of internal stresses by some form of heat treatment is frequently desirable and sometimes essential.

Causes of Internal Stress

There are three main causes of internal stress:

1. Differential cooling or contraction within a single section due to more rapid cooling of the surface as opposed to the interior of the section.
2. Differential cooling between two or more sections, and
3. The resistance of the sand mold itself to shrinkage and contraction of the casting.

(1) The first cause of internal stresses can perhaps best be understood if the case of a particular casting is considered. If a solid cylinder is cast and allowed to cool in the mold, the outer portion of the cylinder will, of course, cool more rapidly than the core and will thus shrink more rapidly. If we consider for the moment only the axial stresses (i.e. those parallel to the axis of the cylinder), it is evident that stresses in directions shown by the arrows in Fig. 1 will prevail. Thus in Fig. 1 the outside layers are in tension and the core

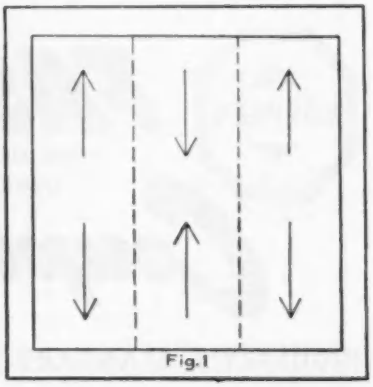

Fig. 1

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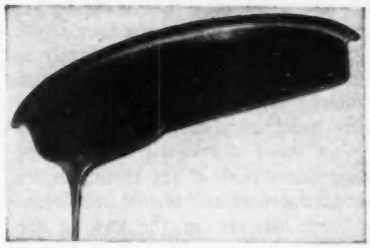
IRVINGTON INSULATING VARNISH DIGEST

Comparative Tests Show Superiority Of Internal Curing

That heat-induced chemical polymerization results in more thorough drying of insulating varnishes and does away with soft, tacky interiors is indicated by studies performed on test lids with various types of varnishes. These studies show that varnishes which dry chiefly by oxidation may remain soft and tacky in the interior, even after prolonged baking, while the internal curing type of varnish, which dries by polymerization, sets throughout after only a few hours of baking.



Varnish on this test lid—one of a type drying by oxidation—baked two weeks at 220° F., remained soft and tacky in the interior

Internal curing varnish on this test lid set completely after only 8 hours baking at 212° F.

Air Drying Varnishes Have Many Applications

Air drying varnishes produced by Irvington Varnish & Insulator Company find wide use both as a final coat on windings already impregnated with other types of Irvington varnish and as a means of protecting other types of electrical apparatus and improving appearance.

These varnishes are also used as coatings on switch boxes, battery trays, conduit boxes, signal boxes and metallic surfaces in general. Varnishes are supplied in both black and clear types. A list of the major types is available on request.

"Deep-Cure" Insulating Varnishes Give Outstanding Performance

Finished Windings Combine High Dielectric, Mechanical Strength with Exceptional Resistance to Chemicals

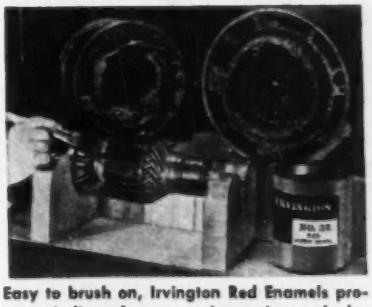
Insulating varnishes that cure throughout by heat-induced chemical polymerization offer unusual service advantages, because this method of curing does away with wet, sticky interiors even in very deep windings. The exceptional degree of penetration of these varnishes and their complete solidification on curing combine to assure a thoroughly insulated, firmly bonded winding. These features prevent shorts caused by chafing of insulation resulting from the movement of adjacent turns.

Thorough impregnation and complete curing result from use of internal curing type varnish on these and many other types of windings

In addition, these varnishes offer high dielectric strength, ranging from 1,700 to 2,200 volts per mil, depending on the particular type of varnish used. Specific formulations are adaptable to a wide range of operating conditions, from stationary coils to high-speed rotating equipment.

Finishing Enamels Protect Windings Against Oil, Dust

Insulated windings can be protected from the harmful effects of oil, moisture, chemicals, water and grease by means of a quick-drying coat of a finishing enamel. Formulated specifically for use as a finishing coat, Irvington Enamels are easily applied by brush and dry rapidly to a tough adherent film. Two major types are: No. 32 red, designed to give the fastest drying time consistent with good protection under most service conditions; and No. 30 red, for especially severe service conditions.



Easy to brush on, Irvington Red Enamels protect windings from corrosive action and also improve dielectric properties

Chemical Stability

All Irvington internal curing varnishes have good-to-excellent resistance to oil, moisture, acids and heat, and the majority of them have good resistance to alkalies as well. Because of this high degree of chemical stability, they are adaptable to a wide range of service conditions. Typical applications include high-voltage coils; radio and TV transformers; low, medium and high speed armatures; field coils; oil-cooled transformers; relay coils.

Production Procedures

These varnishes are adaptable to a wide variety of application processes. The vacuum and pressure method is commonly used to assure the fullest degree of impregnation of deep windings. The varnishes may also be successfully applied by dipping. Brush application is used between layers as coils are being wound. All of these varnishes are adaptable to a variety of baking schedules. Their internal curing properties permit application of multiple coatings with only short, partial curing bakes between coats.

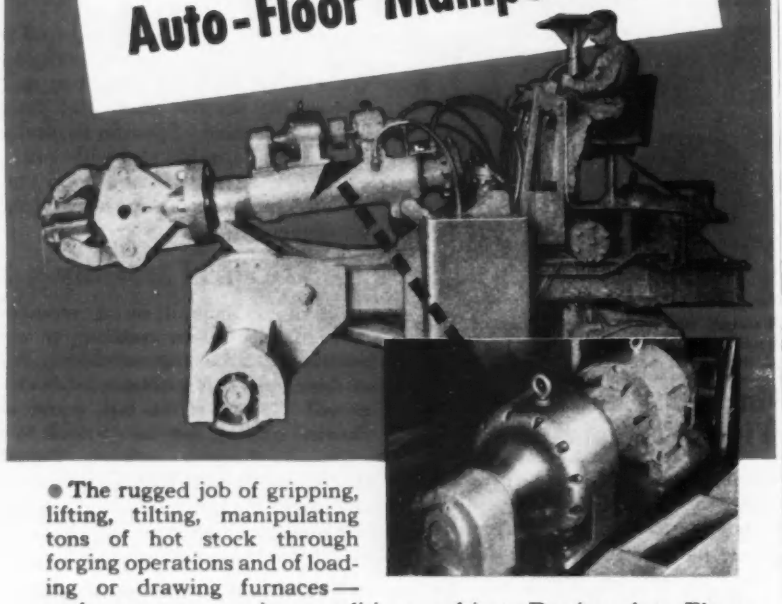
Internal curing varnishes are available in both black and clear types, and in formulations that provide either considerable flexibility or high rigidity in the finished windings. In addition, Irvington's Research Department is prepared to assist varnish users in evaluating the properties of varnishes for specific requirements of service performance, methods of application and baking schedules.

[For further information, write the Sales Manager, Varnish Div., Irvington Varnish & Insulator Co., 10 Argyle Terrace, Irvington, N. J.]

under the twists and shocks of mighty hammer blows

WINSMITH SPEED REDUCERS®

stand up indefinitely on Brosius Auto-Floor Manipulators



● The rugged job of gripping, lifting, tilting, manipulating tons of hot stock through forging operations and of loading or drawing furnaces—such extreme service conditions subject Brosius Auto-Floor Manipulators to a terrific beating. And day after day they take it and like it, and roll back for more!

For very good reasons, Salem-Brosius, Inc., the manufacturer, is a consistent user of Winsmith Speed Reducers for rotation of tongs heads at 22 to 24 rpm on capacities up to two tons. First, they stand up to the twist and shock of forging operations which are imparted to the spindle and transferred through the speed reducer. Second, they are compact, and being forward of the operator they do not obstruct his view of work being done.

The Winsmith (pat.) Differential Gear Reducer used on the Brosius Manipulator is unique among speed reducers. With it, in one single stage in the same housing, reduction ratios of 1.1:1 to 50,000:1 are obtained smoothly and silently—without need of extra parts.

Good to remember: within the range of 1/100 to 85 hp, Winsmith's four basic speed reducer designs—differential, worm gear, helical gear and worm-helical—provide the most complete line available from any one manufacturer.

Write for informative catalog No. 148.

WINSMITH, Inc.
111 Eaton St.
Springville (Erie County), N. Y.

in compression. Since the cylinder as a whole is still at a sufficiently elevated temperature, plastic deformation of the core can readily occur and will largely relieve the compressive stress in the core. However, when, upon further cooling, the core of the cylinder, in turn, contracts, the stresses are reversed, as shown in Fig. 2.

The hotter core material continues to cool and attempts to contract while the surface layers have already reached so low a temperature that the resultant contraction stress can no longer be relieved by plastic deformation, and the stresses shown in Fig. 2 remain locked in the casting.

(2) In the case of a casting, however, stresses arising from differential cooling between two or more sections of a casting are of greater significance than stresses within a single section of the type shown in Figs. 1 and 2. The latter stresses are normally only considered where absolute alignment must be maintained in a machining operation. The slow cooling in a sand mold, in fact, reduces them automatically to a point where they seldom adversely influence physical properties. On the other hand, as already noted, stresses arising from differential cooling of independent parts of the casting either due to different section thicknesses or to their location in the casting are much more severe. The resultant dif-

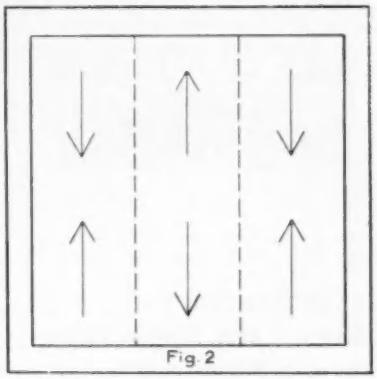


Fig. 2

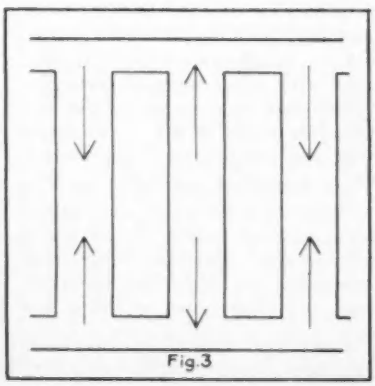


Fig. 3

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YOU CAN TELL AT A GLANCE that the Job's OK

. . . when you use T & B Sta-Kon® Self-Insulated Terminals*

You can look right through the *translucent* nylon insulation on these new T & B Sta-Kon Self-Insulated Terminals—and *see* the stake mark that tells you the joint's electrically sound, mechanically strong.

These new components end the risk of shorts between closely-mounted terminals. Metallic portion retains all the proved advantages of the Sta-Kon design—high conductivity, permanent grip. Lightweight nylon insulation prevents metal-to-metal contact between terminals . . . *without* an extra insulating operation. It withstands action of gasoline, naptha, hydraulic fluids. It's *color-coded* for quick identification.

SIMPLE, SURE ASSEMBLY

One operation stakes terminal to wire with terrific force . . . holds wire insulation firmly inside terminal. SHURE-STAKE Hand Tools apply 1-ton staking pressure *every time*—jaws can't open till full force is exerted. Air tools available too—hand-held or bench-mounted.

*Patent Pending

THERE'S A T&B ENGINEERED PRODUCT for every wiring job in the complete T & B line of fittings for all conductors and raceways.

ENGINEERED RIGHT . . . DISTRIBUTED RIGHT! Sta-kon Self-Insulated Terminals are typical of the many T & B quality fittings recently re-designed to give you outstanding performance at lowest installed costs. Like all T & B fittings, they're furnished 100% through local T & B distributors under the T & B plan.

THE THOMAS & BETTS CO., INCORPORATED

16 Butler Street, Elizabeth 1, New Jersey

MANUFACTURERS OF ELECTRICAL FITTINGS SINCE 1898
ORIGINATORS OF SELF-INSULATED SOLDERLESS TERMINALS IN 1935

Our Field Design Engineers are ready to help you on special fittings problems. Ask your nearest T & B Distributor to arrange to have one get in touch with you.

AMERICAN CHEMICAL PAINT COMPANY

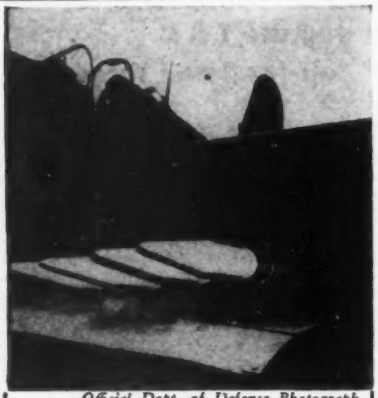
AMBLER CHEMICALS ACP PROCESSES PENNA.

Technical Service Data Sheet

Subject: IMPROVING PAINT ADHESION ON STEEL WITH GRANODINE®

INTRODUCTION

"Granodine" is a zinc phosphate coating chemical which improves paint adhesion on steel, iron and zinc surfaces. In the Granodizing process, a non-metallic crystalline coating is formed on the treated metal. This bond holds and protects the paint finish and thus preserves the metal underneath.



Official Dept. of Defense Photograph

An F4U Corsair with the Navy's new aircraft anti-tank rocket, the "RAM". A Grade I zinc phosphate finish (JAN-C-490) protects the entire external surface of this rocket and provides a durable bond for the specification paint finish.

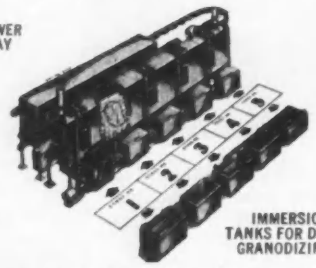
"GRANODINE" MEETS SERVICE SPECIFICATIONS

JAN-C-490, Grade I	CLEANING AND PREPARATION OF FERROUS METAL SURFACES FOR ORGANIC PROTECTIVE COATINGS
JAN-F-495	FINISHES FOR EQUIPMENT HARDWARE
U.S.A. 57-0-2C Type II, Class C	FINISHES, PROTECTIVE, FOR IRON AND STEEL PARTS
U.S.A. 51-70-1, Finish 22.02, Class C	PAINTING AND FINISHING OF FIRE CONTROL INSTRUMENTS; GENERAL SPECIFICATION FOR
MIL-V-3329	VEHICLES, COMBAT, SELF-PROPELLED AND TOWED; GENERAL REQUIREMENTS FOR

GRANODIZING DATA

Granodizing is an easily applied chemical process. Depending on the size, nature and volume of production, Granodizing can be carried out by spraying the parts in successive stages of a power washing machine, by dipping the work in the cleaning, rinsing and coating baths contained in tanks, or by brushing or flow coating the work with portable hand equipment. Typical process sequence and equipment requirements are shown below:

MULTI-STAGE POWER WASHER FOR SPRAY GRANODIZING



PROCESS SEQUENCE
1. Clean
2. Rinse
3. "Granodine"
4. Rinse
5. Final Rinse

IMMERSION TANKS FOR DIP GRANODIZING

NOTE: Equipment can be of mild steel throughout, except in the Granodizing stage, where nozzles, risers, and pump impeller should be of acid-resistant material.

MANY APPLICATIONS

Automobile bodies and sheet metal parts, refrigerators, washing machines, cabinets, etc.; projectiles, rockets, bombs, tanks, trucks, jeeps, containers for small arms, cartridge tanks, 5-gallon gasoline containers, vehicular sheet metal, steel drums and, in general, products constructed of cold-rolled steel in large and continuous production are typical of the many products whose paint finish is protected by "Granodine".

CHEMICALS ACP PROCESSES

WRITE FOR FURTHER INFORMATION ON "GRANODINE" AND YOUR OWN METAL PROTECTION PROBLEMS.

CHEMICALS ACP PROCESSES

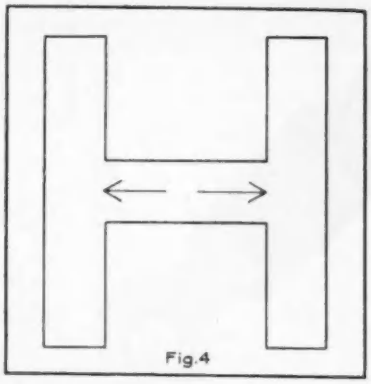


Fig. 4

ferent cooling and contraction rates can and have produced very appreciable and sometimes critical stresses. This problem arises more often with castings for the simple reason that casting permits more complex parts to be produced as a single integral component than is possible using other methods of construction. For example, assuming that it is necessary to produce a casting of the design shown in Fig. 3 (actually such a design should naturally be avoided if possible), it is clear that the two smaller outside sections will cool more rapidly than the thicker central section. Thus, before the central section has completed its shrinkage, the comparatively cold sections can no longer be plastically deformed and thus absorb the shrinkage stress. In other words, the structure is rigid, setting up a tensile stress in the thicker or more slowly cooling section and a compressive stress in the thinner sections. Although in gray iron these stresses rarely reach proportions sufficient to crack the casting, they may lead to distortion and lower the strength of the castings in certain applications. As in the previous instance, the internal stresses arise from the existence at a given moment of a difference in temperature between two or more parts of the casting during cooling.

(3) The third cause of internal stresses is easily seen by a consideration of Fig. 4. The contraction of the casting while still in the mold is hindered in this case by the mold itself, so that a tensile stress is set up in the cross-bar "a".

From these examples some idea can be gained of the desirability and sometimes necessity for again heating castings of uneven section size or cooling rate to a temperature at which the material will be sufficiently plastic to yield and eliminate any existing internal stresses. The need for such stress relief is intensified if the casting is to be used in a critical application.

A further complication that may de-

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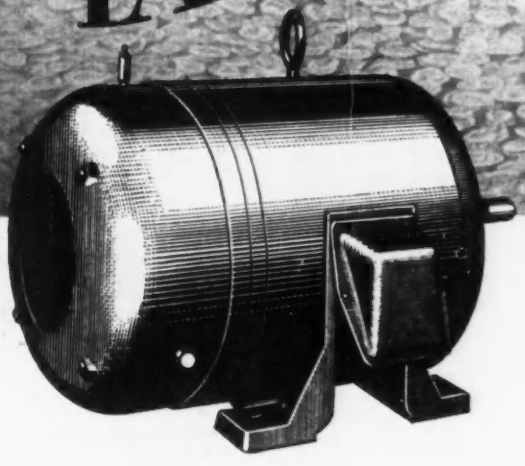

EBCo-built *U.S.S. Perch* in maneuvers off Alaska. Official U.S. Navy photo.

Industry has learned what marine engineers have known since 1880

ELECTRO DYNAMIC builds great motors

To withstand the terrific strains of submarine service, Electro Dynamic motors have long featured *extra-dependable* performance and *extra-rugged* construction to resist stress and prevent twisting and distortion.

E. D. motors for industry, like their famous marine counterparts, are built to stand up under the hardest kinds of uses. Their husky cast frames and housings assure rigidity and resist corrosion. And the special care and superior insulating materials that go into the WINDINGS . . . "the heart of the motor" . . . provide many extra years of dependable, low-cost operation.

There's an E. D. motor for every industrial application. Available in all standard enclosures...1 to 250 h.p. Write today for literature.

E. D. also makes a complete line of Direct Current Motors and Generators. Literature on request.

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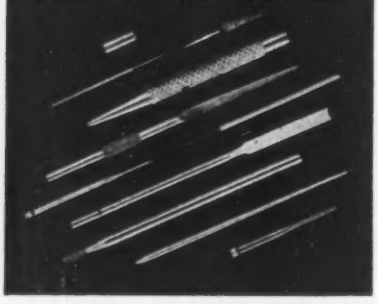
"Joe, who can make these small parts to our close 'specs'?"

"Torrington can, Tom. They have the experience and equipment to maintain precision tolerances on any quantity of small metal parts."

Small precision parts often take more production time than can be spared. That's why many leading manufacturers have turned over their parts problems to Torrington. Using the latest automatic and semi-automatic equipment, our Specialty Department produces hundreds of thousands of parts every day to the exacting specifications of hundreds of customers. These companies—some of them Torrington customers for over 40 years—have learned that they save both time and money when their small metal components are made by Torrington.

Why not send us a blueprint or sample of *your* small parts? We will quickly tell you how little it costs to have uniformly accurate components.

Typical Torrington-Made Parts



THE TORRINGTON COMPANY
Specialty Department
554 Field Street • Torrington, Conn.

Makers of
TORRINGTON NEEDLE BEARINGS

velop in any ferrous casting, and one which can develop special stresses, is the change in volume, i.e. the expansion, which accompanies the cooling of iron through the critical range. This is not important at normal cooling rates but should be considered on very rapid cooling or quenching a casting from temperatures above about 1,500 F.

Results of Internal Stresses

The necessity for relieving internal stresses formed in any of the above ways is dependent on their magnitude. Although, because of the expansion accompanying graphite formation and the low coefficient of contraction, these stresses are less in gray iron than in other cast metals, they can, as already noted, reach a point where (a) the strength of a casting is decreased, (b) distortion follows cooling or machining or (c) cracking will occur in very severe cases. These possibilities should be kept in mind in determining whether stress relieving is advisable.

As concerns lowered strength, it can easily be understood that if an iron of, say, a tensile strength of 35,000 psi has in one of the three manners noted above acquired an internal tensile strength of 10,000 psi, it will have in service an effective tensile strength of only 25,000 psi. Such a stressed condition can conceivably result in failure of the casting when it is subjected to a service load materially lower than the normal tensile strength of the metal used in the casting.

The second, and often the most important commercial consequence of internal stress, is distortion of the casting, a condition which may not show up until the part is machined. The reason for such distortion can be understood if we take the case of a plate such as that shown in Fig. 5a, in which a balance of stresses exists between the core (2x) and two outer sections (x+x=2x). If one of the outer sections were to be machined

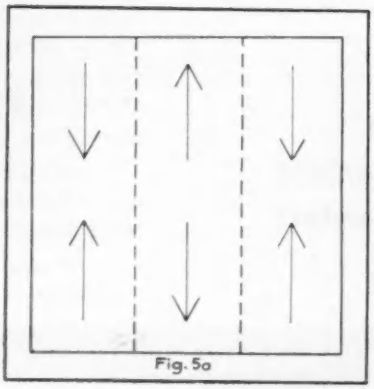


Fig. 5a

CONTROLLED TIMER

at a price you can afford

PRE-SET, TAMPER-PROOF TIMING

Practically non-breakable, Durakool Pre-set Timer Relays have more than proved themselves on the roughest and toughest jobs that could be found. Year by year, their use increases in sensational fashion. Controlled time available from .15 to 20.0 seconds in either normally open or normally closed actions. 3 to 4 week delivery. No waiting. Your production schedule is met.

★ No false contacts
★ No chatter
★ Quiet in operation
★ Eliminates double contacting or breaking of circuit

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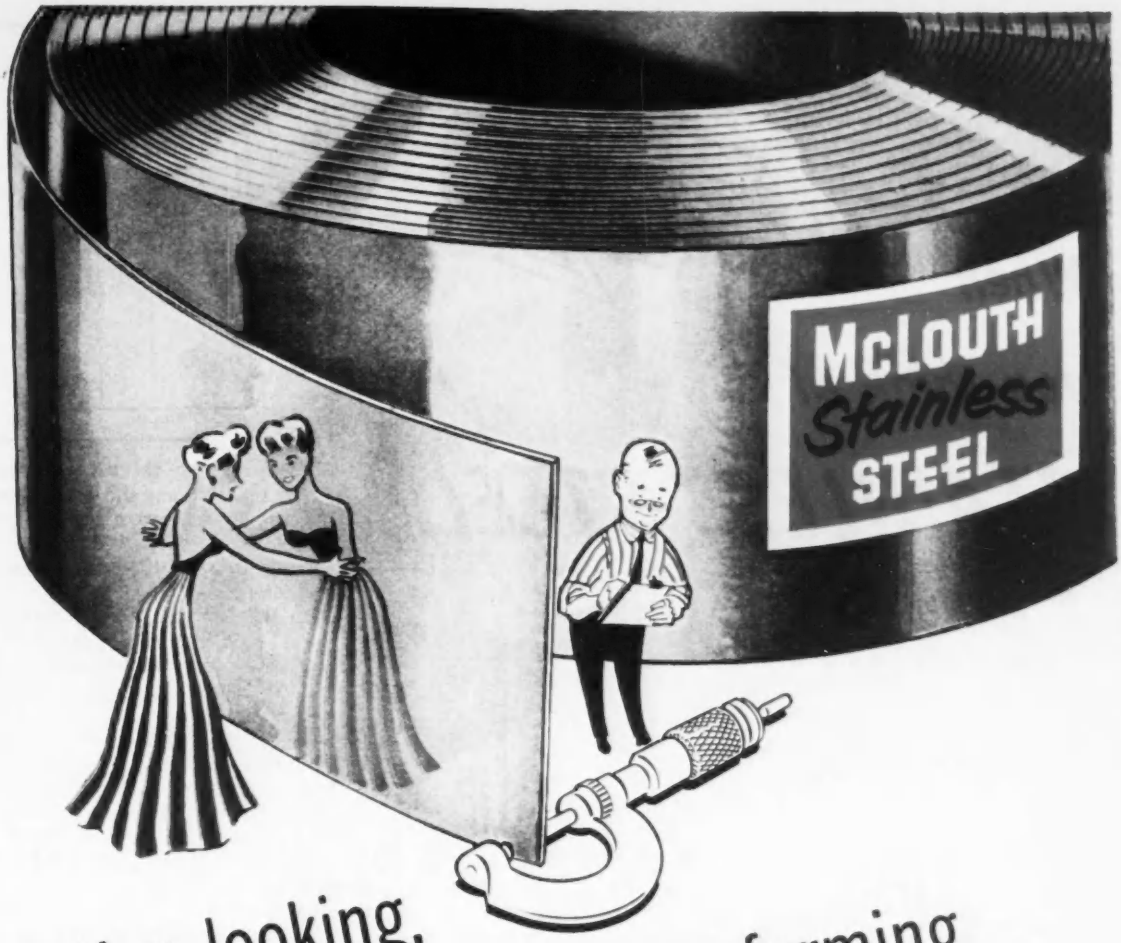
Durakool

ALL-STEEL MERCURY *Timers*



Better looking, better performing

The mirror-like finish and exact gauge of McLouth Stainless Steel gives you better production performance on every job.

McLouth Stainless Steel is manufactured in a wide range of grades and finishes and the exact chemical composition of the steel is determined for every order. It has a high resistance to corrosion, heat and wear to give your products better appearance and longer life.

Ask for a McLouth Service Engineer to analyze your stainless requirements. When the product you make today, or the product you plan for the future calls for stainless, *make it with McLouth Stainless Steel.*

McLOUTH STEEL CORPORATION

DETROIT AND TRENTON, MICHIGAN

HOT AND COLD ROLLED STAINLESS AND CARBON SHEET AND STRIP STEEL

When you think of

STAINLESS STEEL FASTENINGS

think first of

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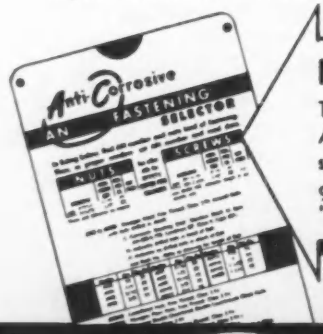
Anti-Corrosive has millions of stainless fastenings *in stock* (probably the largest selection of varieties and sizes in the world) for *immediate delivery*. Anti-Corrosive has the exceptional production capacity that can fill your requirements beyond stock items faster, *better!*



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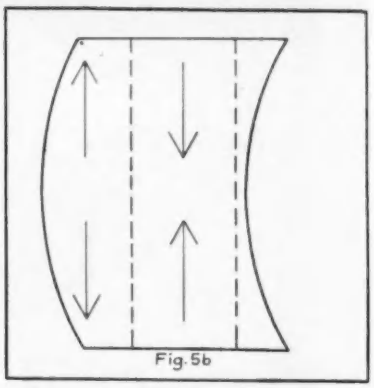

off as in Fig. 5b, this balanced system would be upset, and the stronger stress may cause distortion of the casting. If the stresses are relieved before machining, this distortion can, of course, be prevented.

In the last case, that of cracking, the induced internal stresses have exceeded the ultimate strength of the material, causing fracture even before the casting is subjected to a service load. Although this is not a common occurrence with gray iron (the "hot-tearing" familiar to steel foundrymen is, for example, rare in an iron foundry), it is possible, and should be taken into consideration when the casting is designed. Incidentally, cracking is more common in white iron than gray iron because of the greater contraction and lower inherent plasticity of this material.

Bonded Joints in the Construction of Metal Aircraft

Abstracted from *Aero Research Technical Notes*, June, 1952.

IN COMMON WITH EVERY NEW CONSTRUCTION or production technique in the aircraft industry, bonded joints for light-alloy structures have been developed primarily for economic reasons, benefiting alike both the manufacturer and the user responsible for subsequent servicing.

(1) Production Advantages: When bonding methods are employed, the cost of producing a given joint is to a large extent independent of the surface area involved, whereas with riveting or spotwelding costs are generally proportional to the number of rivets or welds in the joint. Therefore, while conventional methods remain more economical than bonding for the production of joints of small dimensions, the bonding technique offers a considerable economy when large surface areas are to be joined. Bonded joint, moreover, make pos-

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*Did you know that the common Pocket Gopher depends on good seals for protection against his natural enemies? This sturdy-bodied little rodent spends practically all his life in underground tunnels a foot or two below the earth's surface. When coming up to throw out dirt or search for food, he carefully seals all entrances to his burrow with dirt to keep out snakes, weasels, coyotes, foxes or badgers. *The gopher has learned the value of a good seal for lasting protection.*

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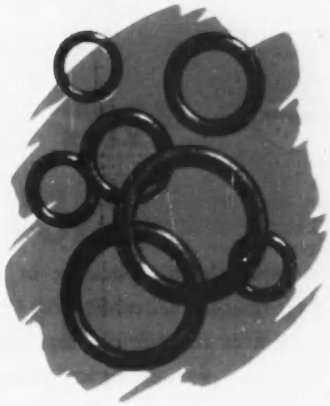
*Specify Minnesota O-Rings for lasting protection. Bulletin available on request.



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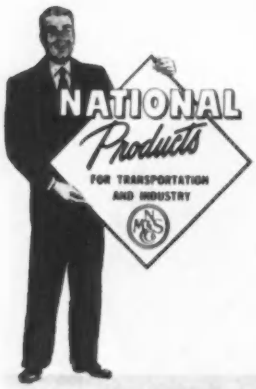

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sible a great saving of time when air- or liquid-tight joints are required for "pressurised" cabins or fuel-tank structures; the elaborate sealing operations indispensable with riveting are completely eliminated.

(2) Advantages in Operating Costs: The economics of aircraft operation require that any new method of joining metals must result in a lower unladen weight so that payload may be correspondingly increased. New techniques must therefore provide structures with a higher strength at the existing weight or equal strength at a reduced weight. To fulfill these requirements bonding must, compared with riveting or spotwelding, give:

(a) Higher shear or tensile strength.
(b) Greater stability in the structure.
(c) Longer life under alternating load (fatigue life).

(1) Shear Strength: It is common practice in the aircraft industry for joints to be so designed that they are loaded in shear, and it will therefore be appropriate to make a comparison between the shear strength of riveted, spotwelded and bonded joints.

A lap joint, consisting of two 1-mm "Dural" sheets with a 13 mm overlap and a spacing between rivets of 15 mm, has an average strength of 1.44 kg per mm joint area when rivets of 4-mm diameter are used. A lap joint with rivets, sheets and spacing of the same dimensions, but with a 32 mm overlap and three rows of rivets, has an average shear strength of 1.76 kg per sq mm.

In joints of the same dimensions, but with rivets replaced by spotwelds, shear strengths of 0.72 kg per sq mm and 0.88 kg per sq mm are obtainable.

If, however, 1-mm "Dural" sheets with 13-mm overlap are bonded together by means of hot-setting adhesives, shear strengths of the order of 2.8 kg per sq mm are obtained.

As far as static strength is concerned, bonded joints compare well with riveted or spotwelded structures.

(2) Stability: An adhesive provides a continuous bond over the entire surface areas of the components joined and thus imparts a higher degree of stability than riveting, which causes the load to be concentrated at certain focal points. In a riveted joint, both components must be sufficiently stable to bear this concentrated loading, whereas, with bonding, the load is spread uniformly via the adhesive layer over the whole of the bonded area. With a bonding process, moreover, it is significant that each com-

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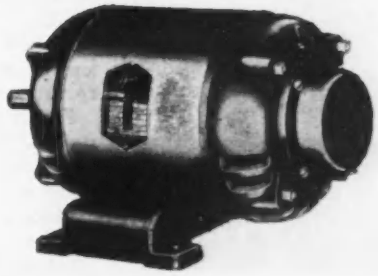
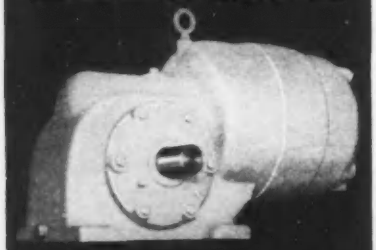


ELECTRA



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ponent supports the other through the medium of the adhesive layer.

Fatigue Life. In recent years it has become clear that aircraft structures must often be of excessive dimensions so far as static loading is concerned in order that their life may be sufficiently long when they are subjected to dynamic loads. Numerous fatigue tests have proved that the absence of stress concentrations in bonded joints offers a great advantage over riveting and spotwelding methods. The Consolidated Vultee Aircraft Corporation made use of this characteristic on an extensive scale by using 'Metlbond' in their ten-engined B-36 bomber aircraft. Here, in the course of preliminary tests on a given structure, the fatigue life using (a) spotwelding, (b) riveting, (c) 'Metlbond', was shown to be 12×10^6, 18×10^6 and 24×10^7 cycles respectively.

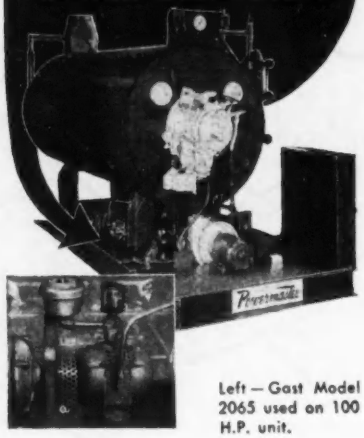
The Bristol Aeroplane Company joined skin panels on an airtight box in which pressure was alternated between positive and negative. On the 0.7-mm panels, L-stiffeners were attached either by means of riveting or by 'Redux.' The riveted specimen failed after 0.3×10^6 pressure cycles as a result of cracks emanating from the rivet holes. The 'Redux'-bonded specimen failed after 4.5×10^8 cycles, due to combined stiffner and sheet failure.

These tests tend to confirm that the use of bonded joints may lead to a reduction of the unladen weight of an aircraft which, in turn, favours greater economy of operation. This economic advantage is strengthened by a further characteristic of the bonding method, the capacity to produce skin surfaces of exceptional smoothness and thus achieve lower aerodynamic resistance without the disadvantage of increase in weight.

The application of metal bonding in aircraft structures offers many advantages, but the careful control needed for operating the process requires trained man-power. In Holland, where the aircraft industry has always had available a larger proportion of skilled workers than could be found in other countries, extensive use of metal bonding will prove advantageous. This however, remains true only so long as bonded structures are designed as such.

Finally, grateful acknowledgments are due to the Nederlands Institut voor Vliegtuigontwikkeling, where the significance of the new developments has been appreciated and where facilities have been made available for a detailed study of the subject.

GAST rotary air compressors ATOMIZE FUEL OIL UNIFORMLY for "Powermaster" Steam Generators



Left — Gast Model 2065 used on 100 H.P. unit.

PROBLEM: Select a compressor to supply uniform, pulseless air volume for atomizing fuel oil in the combustion chamber of Orr & Sembower "Powermaster" Boilers.

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ONCE AGAIN you can see how Gast Rotaries — plus concentrated experience with air power, low vacuum and pressure — helped solve a specific problem. Have you considered the advantages of Gast Rotaries on your product? Write us, outlining your problem — you'll receive prompt cooperation. "Air may be your Answer!"

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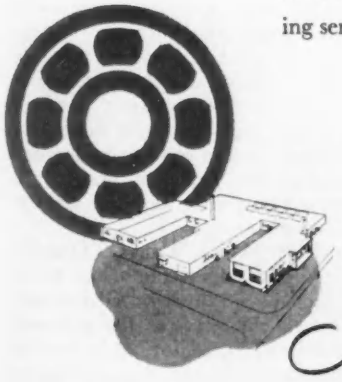

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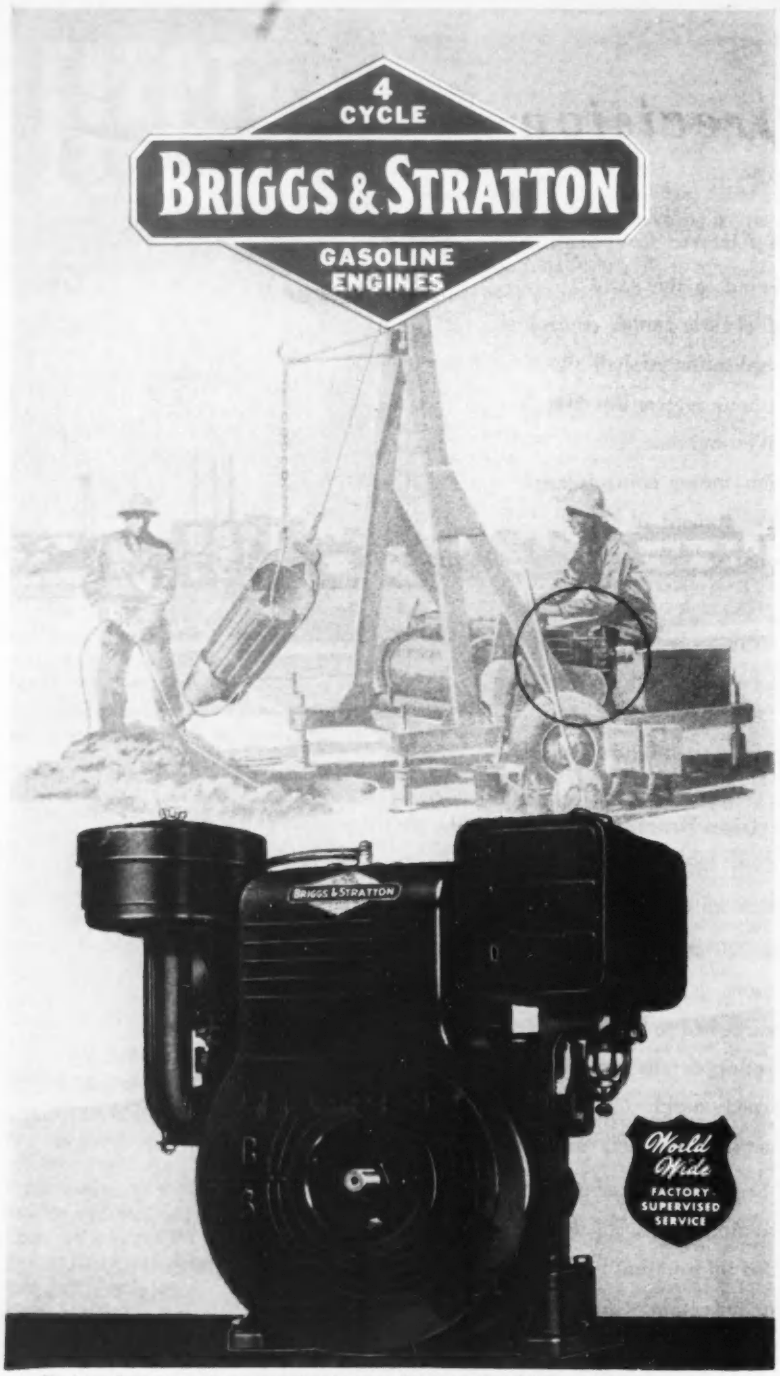

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OUR READERS SAY

Finishing Metal Products

To the Editor:

I have been searching for a manual or book covering "Mechanical and Chemical Finishing" of metals and alloys. I do not know the actual name of such a book, but I felt that you could assist me in securing an authentic up-to-date handbook.

We are engaged in the manufacture of airborne instruments, and specific breakdowns on techniques, relative costs, hazards and limitations on such progresses as: Irridate, Alumalite, Pentrate, Dulite, Alrok, Black Oxide (and all others recommended for Air Force installations) would be desirable. —C. B. HOLMES
Lear, Inc.

Ed—The best book on the subject of metal finishing with which I am familiar is entitled "Finishing Metal Products" by Simonds and Bregman, published by McGraw-Hill Book Company. This book, now in its second edition, sells for $4.00.

It has sections on the standard finishing methods, and also describes many of the special processes.

Patent Difficulties

To the Editor:

I am an old subscriber and greatly appreciate the vast good that you have done for us thru your valuable publication. At this time, I am giving to you a tip about an opportunity to do us even more good thru your pages.

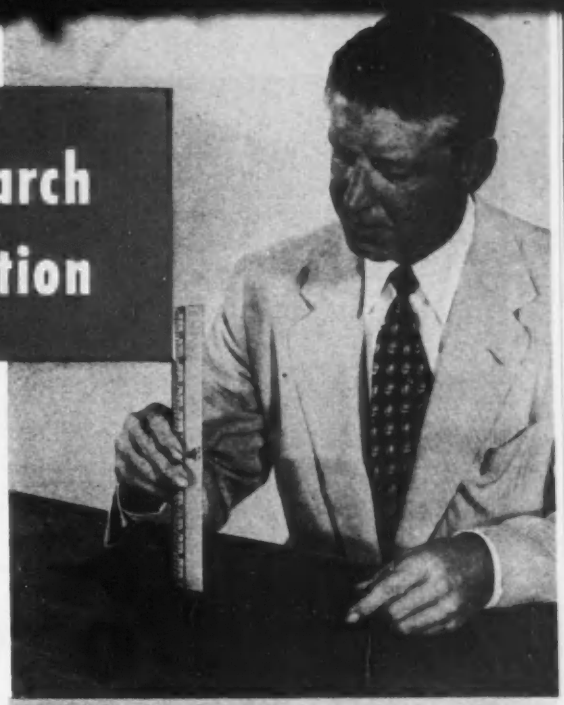
The President just signed into law a new set of regulations that will govern the U. S. Patent office.

A Flash of Genius will no longer be required before you can be granted a patent. This makes it possible to obtain a patent after long toil and experimentation.

In 1941 Justice Wm. O. Douglas declared that an invention had to be the result of a "Flash of Genius and not merely the result of the skill and experience of the calling" to be worthy of patent.

In June 1948 I sold a pilot model of a room cooling fan to a fan manufacturer. The fan was new, very beautiful to look at, distinctive, quiet, and

National Engineering Research finds the *economical* solution



Phenolite postformed expansion joint cover.

The problem:

to insulate a 5 kilovolt, 1500 ampere bus bar installation

Recently I-T-E Circuit Breaker Company of Philadelphia had the problem of *completely* insulating 5 kilovolt, 1500 ampere 3 phase bus bar units for an Atomic Energy Commission installation. It was simple enough to insulate the bus bars with oval Phenolite tubing. But, to completely insulate the bus supports and expansion joints was a real problem. I-T-E's engineers showed us what they wanted . . . postformed Phenolite insulating covers . . . drawn deeper than anything we had ever attempted. Our engineers tackled the problem.

Expansion joint with and without Phenolite insulating covers.

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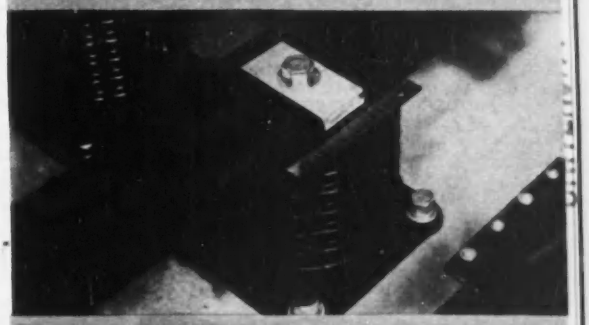
Perhaps *your* problem doesn't involve the insulation of 5 KV, 1500 ampere bus bars. But maybe you have an insulating problem where National can give you some real help in solving how to do your certain job economically. Write us, our engineering service is immediately available.



Bus support with and without Phenolite insulating covers.

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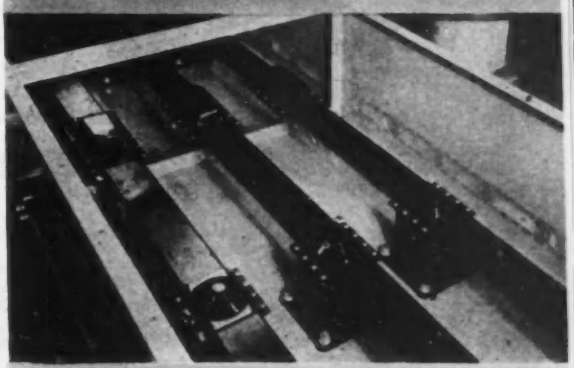

Completed installation, showing Phenolite insulation for bus bars, supports and expansion joints.

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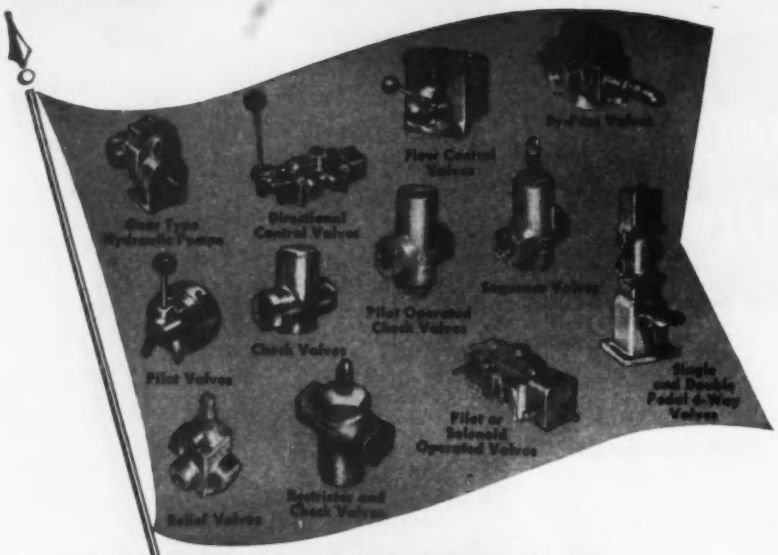

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had great air throwing power. I also sold to him, for a small royalty, whatever patent rights the Patent Office might grant to me in a patent to be obtained by him in my name. In 1951 some 10,500 of the fans were made and sold with complete satisfaction; this year, 1952, fully twice as many should be sold. In July 1952, this manufacturer told me that no patent could be had, and for that reason he would cease to pay me any more royalties.

The fan design is very good, the manufacturer's tools are made, and he will keep on selling same and deprive me of any return for the years of work that I put into that creation.

The ideas and experimentation that made that fan possible are the result of over 20 years of research in fan engineering, fan development work, and air flow study, and about which the said manufacturer or any of his employees know practically nothing.

Because the law has just been changed in regard to this "Flash of Genius" requirement, and about which I never could get a full understanding, I want to ask a very important question.

Would I now be entitled to make a new application for patent on my room cooling fan, now in production by this manufacturer, so that I could now obtain a patent that is my just due?

With the patent accomplished, I could look forward to receiving the very small royalty of ten cents each for the life of the patent.

The fact that I am now 65 years old, receive some social security, and am in great need of these royalties just to pay bare living costs, has of course no standing in court, even though it is of the greatest importance to my wife and to myself.

Another very important question I want discussed. Does the Patent Office have the right to dig up even foreign patents that are taken out for water turbines and water wheels, and pick out from them foil shapes that look like mine, and say that they might be applied for air use and in so doing cancel out my development in fans for air flow fans?

My development is new and basic, and the result of years of study looking for the answer that I have obtained. In years gone by I have been granted over 20 patents and sold almost all of them.

—CHARLES P. GRIMES

Ed—Your letters are always interesting and inspiring. We have been giving some thought to an article on the new status of patents and inventions

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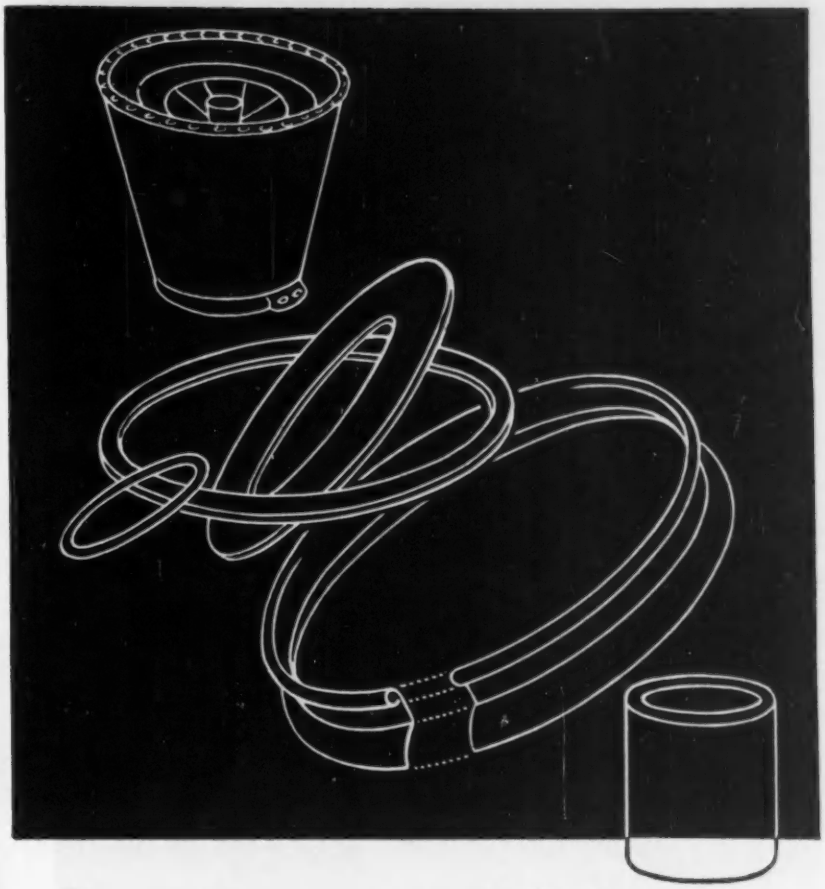

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- Complete Product Assembly
- Every Modern Finishing Service

Detroit Ave. at W. 93rd St., Cleveland 2, Ohio

and your letter brings the matter to a head.

With reference to your experience with the fan manufacturer, I am not in a position to pass judgment, but on the basis of the information contained in your letter, it appears to me that the fan manufacturer was unfair. You gave him the idea, he is manufacturing the product on the basis of your design, and he therefore is indebted to you for the development of this product.

With reference to the question as to whether you can now make another patent application on a room cooling fan, I am sorry that I can give you no advice. The patent laws are so technical that it requires a specialist in that field to answer your question.

With regard to the second from last paragraph of your letter, it doesn't seem correct that the Patent Office should use foreign patents relating to and concerning liquids and apply that reasoning to gas. Although water and air are both fluids, they are entirely different in every respect. The dynamics that apply to liquid processes do not apply to gaseous processes.

Wants Details on Hydro-Forming

To the Editor:

We are interested in the new process known as hydro-forming, and would appreciate it greatly if you would send us details regarding same.

—MYRON X. FELD
American Technion Society

Ed—In answer to your inquiry concerning the new process known as hydro-forming, we do not have this information here at PRODUCT ENGINEERING. We suggest, however, that you contact the following company, which doubtless can supply you with details: Mr. Walter Kauders, Publicity Manager, Hydropress, Inc., 201 E. 56th St., New York 22, N. Y.

High Speed Bearings

To the Editor:

In a search for suitable bearings for small spindles rotating at very high speeds (50,000 rpm and higher), our attention has been attracted to air bearings. Consequently, it would be appreciated if you could supply us with some source of information on any articles or papers on the subject of air bearings. —CHARLES L. BABB
Buckeye Tools Corp.

Ed—I am forwarding to you three

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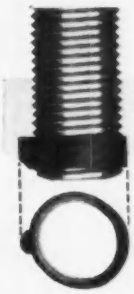
THERE IS NO OTHER FASTENER LIKE THIS!



IF YOU are one of those people who believes a cotter pin is the only way to hold anything positively on a bolt you will be surprised at tests made on Security Locknuts. Authoritative tests have proved Security Locknuts practically vibration proof.

Security Locknuts stay "put" where you wrench them even in the face of vibration that destroys the bolt. They permit accurate adjustments with a torque wrench. They are complete as a unit. There is nothing to line up. Installation involves only one operation and there are no holes to weaken the bolt or stud.

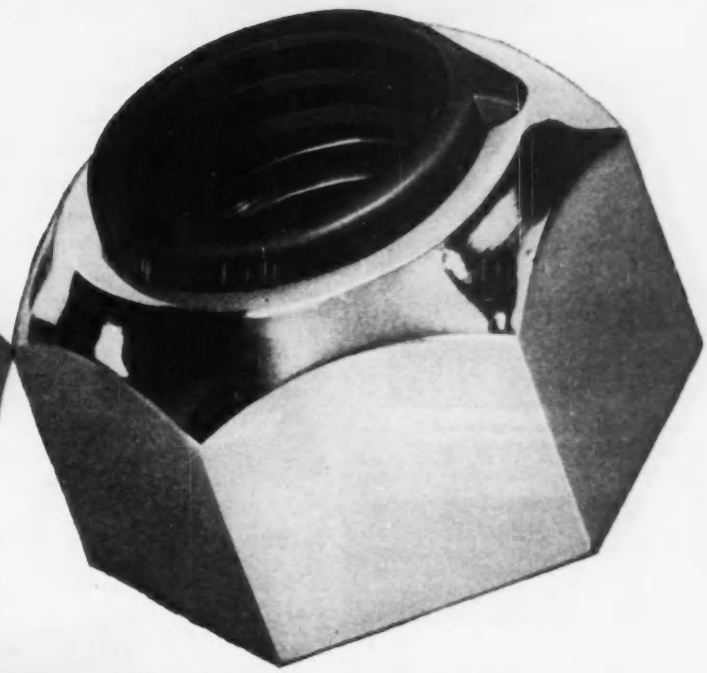
Security Nuts can be adjusted and re-adjusted any number of times but more important, they can be *removed and re-used over and over again without materially losing their locking power and without damage to the bolt.* We'd like to have you see the results of these tests. If you have a vibration or fastener problem. Security Locknuts are a dependable solution and may save you money over methods you are now using.

Security Locknuts are made in 3/8 in. to 2 in. bolt sizes. Ask to see the Security Locknut Tests.

SECURITY LOCKNUT CORPORATION
North Ave. and 15th Ave., Melrose Park, Ill.

This picture shows a cross-section of a Security Locknut. The insert, indicated removed, is of high quality, heat treated, alloy spring steel and becomes a permanent part of the nut.

The insert is elliptical in shape and this design causes the retainer to grip the bolt with the terrific tension that only spring steel of great strength could exert and prevent the nut from turning. Simple—dependable—positive!



SPECIAL OFFER!

Here's an easy way to arrive at thread tolerance figures. Ask for a Security Thread Tolerance Chart. Just spin the dial and you have the figure you need. Send the coupon. It's yours for the asking.

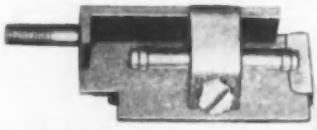
Security
The Nut You Can't Shake Loose

SECURITY LOCKNUT CORPORATION
North Ave. and 15th Ave., Melrose Park, Ill.
Please send me without obligation:
☐ One of your Thread Tolerance Charts.
☐ We have a fastener problem and would like to know more about Security Locknuts.

Company Name_____
Address_____
Town_____ Zone___ State_____
Signed_____

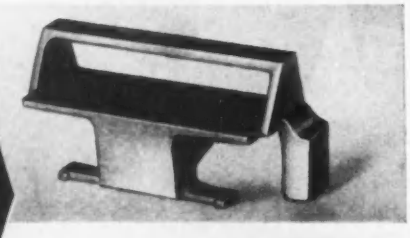
The production of a light weight, rugged brush holder for use with aircraft generators posed a problem for General Electric. They wanted a high-quality, rigid brush holder at reduced cost, produced by a process that afforded closer control of tolerances.

Atlantic was consulted and the recommendations they made on the brush holder design provided more than ample strength. The Atlantalloy process provided the close tolerances and lower cost.



Old brush holder designed by General Electric for use on aircraft generators.

New brush holder designed in collaboration with Atlantic engineers and produced by the Plaster Mold Process.



WRITE for a copy of "Quality Precision Castings for Industry" on your Company letterhead. This booklet explains how the plaster mold process cuts production costs, and includes specifications on Atlantic's alloys.

CASTING and ENGINEERING CORP.

articles on the subject of air lubricated bearings which have appeared in PRODUCT ENGINEERING within the last year. I think that these are the only articles on the subject which have appeared recently.

I think that you will find that these provide much of the basic information you need for possible use of this type of bearing.

Pulse Transformers

To the Editor:

We are very interested in learning the source of the article in the Technical News Section of the July issue on the New Pulse transformers developed by the National Bureau of Standards. Could you give us any information on whom in the Bureau of Standards we might contact in regard to the new unit? —T. E. COATSON
Electronic Engineering Co.

Ed—You may receive additional information by writing to: Mr. Reeves Tilley, Manager of Technical Publications, National Bureau of Standards, Connecticut Ave. at Van Ness St., N. W., Washington, D. C.

Paper Stock Agitator

To the Editor:

Could you send me any information on the theory of paper stock agitation? I am interested in the spiral backswept turbine type of impeller and desire information on impeller size, power required, and rpm for gentle and continuous stock agitation in vertical cylindrical chests of 1000-2000 Imperial gallons capacity.
—F. A. TAYELOR
Letson & Burpee Ltd.
Vancouver, Canada.

Ed—We suggest you contact the Mixing Equipment Company, Inc., 135 Mt. Read Blvd., Rochester 11, New York, or the Worthington Machinery Corporation, Harrison, New Jersey.

Wants Old Reprints

To the Editor:

We are interested in obtaining some reprints of the article "Electrical Indicating Instruments" by Mr. L. F. Parachini which appeared in the January, 1947 issue of PRODUCT ENGINEERING. We would like to obtain about thirty copies of this article if reprints are still available.

Please advise us as the possibilities of obtaining these copies. We would

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AIR CONDITIONER PARTS
York Corporation

HEAVY-DUTY SOLDERER
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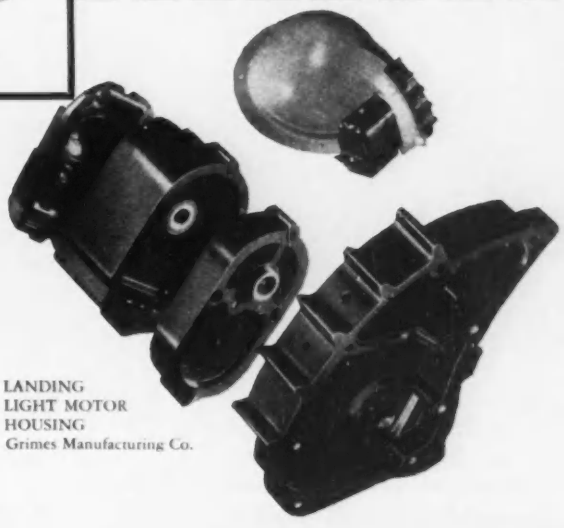
Your custom molder can help...with DUREZ phenolics



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Grimes Manufacturing Co.

● When light weight calls the turn in your selection of materials...and more and more it *does* these days...weight-saving is seldom the sole factor.

Here are four examples that show how other manufacturers are obtaining, in molded phenolics, the light weight plus the *other* characteristics they want in large and small units.

In the air conditioner slinger rings, costly machining of the material formerly used was eliminated...the Durez molding is *pre-balanced in the mold.* Being self-insulating, the fan housing needs no separate insulation. The floor-polisher hood is lasting protection against dirt and moisture, absorbs mechanical shocks without nicking or scratching.

Cost is held down in aircraft landing light parts by molding-in all flanges, holes, ribs, and metal inserts. The soldering tool housing resists heat, is safe and comfortable to use.

Production economies, savings in shipping costs, and user benefits are all at your command in those most versatile of all plastics...the phenolics. All along these lines new ideas await your investigation. Talk with your Durez molder...or with our technical staff.

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require Control in Melting

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LEBANON STEEL FOUNDRY
Lebanon, Pennsylvania
"In the Lebanon Valley"

CIRCLE L LEBANON Steel and Alloy Steel Castings

be agreeable to paying a nominal charge if required to obtain these copies.

In the event that you do not have reprints available and know where copies can be obtained, we would appreciate your advising us.

—H. B. WHITAKER
Underwriters' Laboratories Inc.

Ed—I am sorry to say that we do not have additional copies of the article "Electrical Indicating Instruments" which appeared in our January 1947 issue. We can supply you with 100 reprints, which is our minimum number, done photo-offset for $50.

Unfortunately, that is the best price we could work out on this particular article, since it is an odd-sized 9-page piece and would require a tipped-in sheet on a standard 8 pages. Also, in quantities as small as this, the price is always high.

If you can do better with your own printer, we shall be glad to extend to you permission to offset this one article for your own use.

Foreign Source of SiO

To the Editor:

In the May 1952 issue of PRODUCT ENGINEERING, page 304, a Mr. Julian B. Pinto asked for SiO.

Please inform me, so that I can get him SiO from Germany, which is suitable for the intended purpose. He should contact me.

—KARL-JOSEF LAIB
Luningstr. 43
(21b) Lippstadt, Germany

ERRATA

July 1952, page 121. *Selecting Motor-Mounted Magnetic Brakes.* Top of first column—"exceeds four to six per hour" should read "four to six per minute." Page 123, middle of third column—"removal of brake power" should read "removal of motor power."

July 1952, page 175. *Fine-Pitch Gear Drawing Data Required to Assure Quality.* Bottom of first column—"0.09945" should read "0.9945."

August 1952, page 159. *Converting Decimal Fractions to Actual Gear Rates.* Equation (13) should read $a(b+d)-b(a+c)=-v$. Right hand column, second fraction should be 0.528302.

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FOR COOLANTS, LUBRICANTS, AND ABRASIVE LIQUIDS
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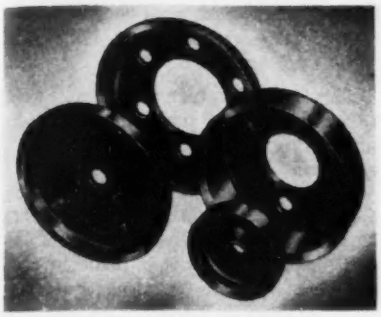
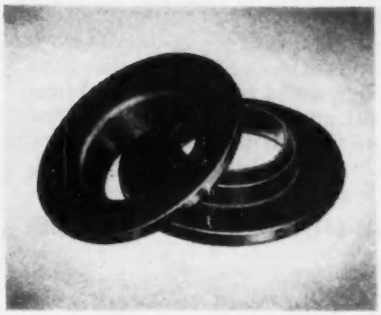
Illustrated and described below are the types available.



CUP PACKINGS

Made of leather or rubber. Installed on piston head or backing plate. Sealing lip and outer side wall form dynamic seal on cylinder wall. Follower plate forms compression seal on bottom of cup. Expanders adaptable when needed.

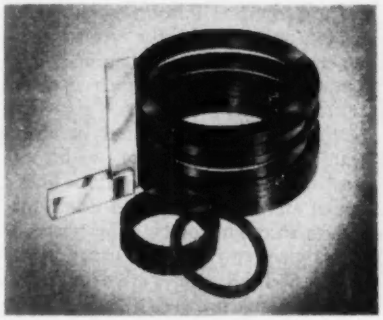


FLANGE PACKINGS

Made of leather or rubber. Installed in recess around a rotating or reciprocating shaft. Sealing lips and inner side wall form dynamic seal on shaft. Gland nose forms compression seal on flange. Expanders adaptable when needed.

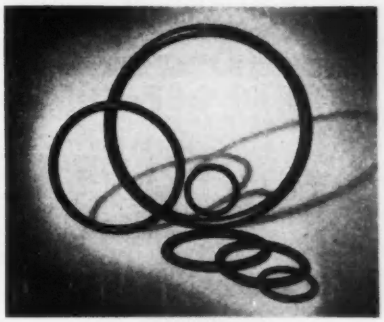
U-PACKINGS

Made of leather or rubber. A completely mechanical seal installed in recess on cylinder wall or piston head. Sealing lips and side walls form dynamic seal inside and outside. Pedestal ring or filler required for best service. Expanders also adaptable when needed.



V-PACKINGS

Made of leather or rubber. A complete mechanical seal, preferably installed in sets in a recess on cylinder wall or piston head. Sealing areas or "stack height" (the area at ends of inside and outside legs) form dynamic seal inside and outside. Male and female adapter rings required, metal preferred. No expanders are needed but spring tension is sometimes employed.



O-RINGS

Made of rubber. Self-sealing from either direction. Excellent for pressures under 1500 psi; used with pressures up to 3000 psi when engineered properly. Installed in a small recess in wall or piston head; also as a static seal. High finish and exact fits required for all parts that contact an O-Ring Packing.

OIL SEALS

Made of leather or rubber, usually incorporating a metal case or supporting ring. Installed around a rotating or reciprocating shaft to retain or exclude fluids, semi-fluids, dust, dirt, etc. Provides single and multiple sealing lips. Oil Seals are generally made to exact specifications to meet specific requirements.

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Simple construction, fewer parts make assembly and disassembly easy – also mean longer life.

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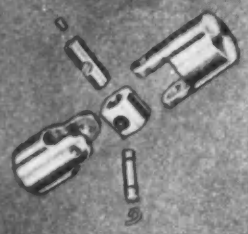

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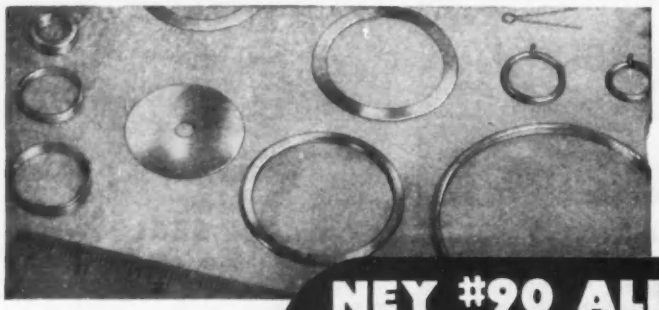

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NEY #90 Alloy, overcomes many of the disadvantages of coin silver when used in slip ring and commutator bar applications. Actually a modification of coin silver, NEY #90 is subjected to a carefully controlled processing that produces a uniform hardness of 120-130 Brinell which has been found best for slip ring type applications. Since performance is also markedly influenced by surface condition, especially when brush pressure must be low, NEY #90 Alloy rings are given a specially developed finish that greatly reduces wear and electrical noise. NEY #90 Alloy is available in seamless tubing in all sizes up to 4" O. D., also in the form of plate, rod, wire and fabricated parts.

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NEW BOOKS

Practical Descriptive Geometry

HIRAM E. GRANT; *Head of the Department of Engineering Drawing, Washington University.* 253 *pages,* 6x9 *in. Published by The McGraw-Hill Book Co.,* 330 *West* 42*nd St., New York* 36, *N. Y.* $4.

This textbook correlates and integrates theory and practice instead of considering each a separate entity. The author is well aware that practical problems, because of the nature of their given information, frequently cannot be solved without considerable difficulty if an attempt is made to derive their solutions by using the typical theoretical approach. Components of the machine control the practical problem's given information. For exemple, a theoretical problem normally asks that a line be drawn tangent to a given parabola, while a practical problem asks that a parabola be drawn tangent to a given line.

Since accuracy is a vital part of drafting, the text devotes a chapter to it. Here are discussed the errors which on occasion become magnified and that may yield results which may be far from correct. The errors discussed are those that are produced by inaccurate drafting equipment, width of line, intersection of projection lines, sizes of arcs and circles, and directions of lines through points. The purpose of this chapter is to call attention to the possibilities and the magnitudes of the inaccuracies.

Problems are not included in this text, since a special set of problems entitled *Practical Descriptive Geometry Problems* has been designed for use with this book.

The Million Dollar Lecture and Letters to Former Students

ERWIN HASKELL SCHELL, *Professor, Massachusetts Institute of Technology,* 6 x 9 *in.,* 177 *pp, Published by McGraw-Hill Book Co., Inc.,* 330 *West* 42 *St., New York* 36, *N. Y.,* $3.

An informative and practical book, The Million Dollar Lecture shows the many opportunities for self-improvement and points out the difficulties faced by young men just starting a career. The author discusses the causes behind such pitfalls as impatience, overambition, and indirection, and gives advice on the many difficulties

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Divided into three parts, the first section is devoted to the lecture and such topics as: the resource of habits; the resource of friendship; the resource of cooperativeness; the resource of incentives; and hazards of the present and future.

The second part covers the commentaries on the lecture.

Part Three is devoted to his letters to former students, and covers such points as: administration as a career; the nature of administration; the road to administration; the demands of administration; recreation and recuperation; stimulus for action; problems without solution; guides to accomplishment; new contours of leadership; key factor; and living with ourselves.

The message is to men who have or will have responsible positions in the industrial future of the country. The author urges a philosophy of life, and presents a philosophy of business administration, "Administration is, at bottom, the maintenance of mutual advantages for all the human interests either directly or indirectly involved in a man-made enterprise."

Electrical Drafting and Design

CALVIN C. BISHOP, *Third Edition*, 267 *pp*, 6x9 *in. Published by McGraw-Hill Book Co., Inc.*, 330 *West* 42 *St., New York* 36, *N. Y.* $4.50.

This book is aimed at the person who plans to enter the field of electrical design. It covers the following items: general instructions for mechanical and electrical drafting; use of symbols, alternating- and direct-current circuits shown by symbols, and typical complete diagrams; metal-clad designs, circuit diagrams, layouts and bills of materials for a direct-current generator switchboard; modern metal-clad construction of a switchboard for 2,300 v service; design of an outdoor station; residence wiring; layout of wiring; illumination engineering, layout, and wiring; design of industrial plant wiring; and an appendix including appropriate tables and charts.

It was found that while the schools taught good courses in mechanical drafting, and while graduates could turn out good drawings of parts of machinery and many had a good understanding of electrical apparatus and circuits, practically none had training in properly showing how drawings should be made to convey to the contractor how electrical work is to be

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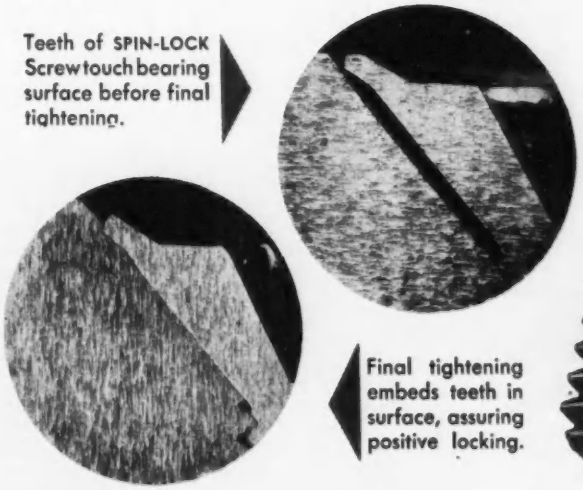
SPIN-LOCK is neater (fastens flush)... safer (no projections)...*easy to drive* in hard-to-reach spots. It makes excellent electrical contact and is oil- and water-tight around the head.

Hex, pan, truss, flat heads. Write to us or any of the companies below for complete data on types and specifications.


Teeth of SPIN-LOCK Screw touch bearing surface before final tightening.
Final tightening embeds teeth in surface, assuring positive locking.

Spin-lock

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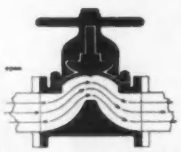
Hills-McCanna Diaphragm Valves can eliminate the problems involved in valving many of the so-called "hard-to-handle" fluids. By employing a simple pinch clamp principle, Hills-McCanna valves put an end to leakage, repacking and contamination.

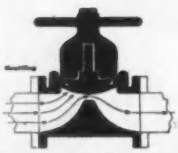
Hills-McCanna Valves are available handwheel or lever operated or for operation by pneumatic or hydraulic cylinders, diaphragm motors, electric motors, etc. Choice of 14 diaphragm materials, 49 body materials. Sizes from ⅜" to 14". Suitable for pressures to 150 psi., temperatures to 180° F. (higher with special materials). Screwed or flanged connections.

Write for Catalog V-52, HILLS-McCANNA CO., 2444 W. Nelson St., Chicago 18, Ill.

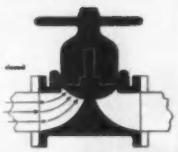
THIS SIMPLE PRINCIPLE ASSURES POSITIVE LEAK TIGHT VALVING



Compressor is raised, lifting diaphragm by means of a stud molded into the material.



Compressor and diaphragm partially lowered. Compressor design guides and supports diaphragm.



Compressor presses diaphragm tightly against weir, pinching off flow and making a tight seal.

HILLS-McCANNA
saunders patent diaphragm valves
Also Manufacturers of Proportioning Pumps
Force Feed Lubricators • Magnesium Alloy Castings

carried out. This book was written to acquaint the student with the methods of representing electrical wiring familiar to the electrical contractor.

This edition has been brought up to date in accordance with recent advances in wiring and electrical construction procedures and with the latest revision of the National Electrical Code.

Illustrated Petroleum Dictionary and Products Manual

Compiled and edited by the editorial staff of the Petroleum Educational Institute, 502 *pp,* 6 x 9 *in. Published by Petroleum Educational Institute.* 9020 *Melrose Ave., Los Angeles* 46, *Calif.* $8.

This book has two purposes: First, to provide information useful to sellers, buyers, and consumers of petroleum products on the subject of product information; and Second, to make available a dictionary of terms commonly used in the petroleum, and other industries connected with petroleum, its products and the equipment utilizing these products. It is prepared on an elementary level and is especially designed for those who do not possess a technical background in petroleum.

To sales personnel, purchasers, and consumers of petroleum products, this book offers a valuable contribution to their knowledge of fundamentals and applications of petroleum products.

Although written in dictionary style, it is arranged so that lay personnel can acquire an intelligent and interesting conversational knowledge of petroleum products by merely reading it. To the student or newcomer in the petroleum industry, it offers a liberal education of a practical nature in petroleum and its many commonly used products.

Practical Calculus

C. I. PALMER *and* CLAUDE E. STOUT, *Prof. of Mathematics and Engineering Mechanics, General Motors Institute.* 470 *pages,* 5 x 7¾ *in. McGraw-Hill Book Co., Inc.,* 330 *W.* 42*d St., New York* 36, *N. Y.* $5.

This is a standard manual known for its practical exposition of calculus. It explains what calculus is and shows how and when it can be used to get quicker, easier solutions to many mathematical problems encountered in industrial and shop work.

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Hills-McCanna Diaphragm Valves ca eliminate the problems involved in valv ing many of the so-called "hard-t handle" fluids. By employing a simpl pinch clamp principle, Hills-McCann valves put an end to leakage, repackin and contamination.

Hills-McCanna Valves are availabl handwheel or lever operated or fo operation by pneumatic or hydrauli cylinders, diaphragm motors, electri motors, etc. Choice of 14 diaphragn materials, 49 body materials. Sizes fron ⅜" to 14". Suitable for pressures to 15 psi., temperatures to 180° F. (higher wit special materials). Screwed or flange connections.

Write for Catalog V-52, HILLS McCANNA CO., 2444 W. Nelson St. Chicago 18, Ill.

HILLS-Mc

saunders patent diaphragm valves

Also Manufacturers of Proportioning Pumps Force Feed Lubricators • Magnesium Alloy Castings

PAG

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This edition has been brought up to date in accordance with recent ad-

shows how and when it can be used to get quicker, easier solutions to many mathematical problems encountered in industrial and shop work.

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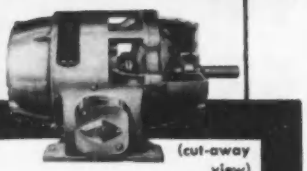

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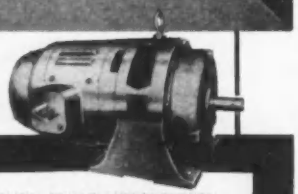

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with little mathematical training a thorough understanding of how calculus can be applied to practical problems, the authors avoid involved mathematical terminology and phraseology throughout. The explanations are as non-technical as possible without loss of accuracy. The previous edition's unified presentation of differentiation and integration is preserved in line with modern trends in the field. The book's emphasis on applications, its integrated treatment, its careful presentation of methods and meanings, and its well-amplified illustrations and worked-out examples all combine to make it an established standard in its field.

New material has been added to this edition on: Newton's method of approximating the solution of a numerical equation; approximate integration; differential equations; cylindrical and spherical space coordinates; and equations and graphs of the more common surfaces in rectangular coordinates.

Past Examinations for Professional Engineers, New York State

JOHN D. CONSTANCE, 625 *Hudson Terrace, Cliffside Park, N. J.* $1.50.

This is a compilation of past examinations of the University of the State of New York covering the period January, 1943 through February, 1952. All requests should be mailed to the author at the address given above.

Advanced Strength of Materials

J. P. DEN HARTOG, *Professor of Mechanical Engineering, Mass. Inst. of Tech.* 379 *pp*, 6½ x 9¼ *in. Published by the McGraw-Hill Book Co., 330 W. 42nd St., New York* 36, *N. Y.* $8.50.

A new text by a leader in the field of applied mechanics, this volume is specifically designed to bridge the gap between books devoted to strength of materials and those dealing with theory of elasticity. It assumes a level of knowledge of elementary strength of materials as attained after the customary one term course in engineering colleges and the ability to use the calculus and differential equations.

The first part of the book, which covers torsion, stresses in uniform and non-uniform rotating disks, membrane stresses in shells, and beams on elastic foundations, was developed for senior

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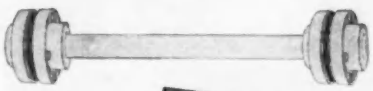

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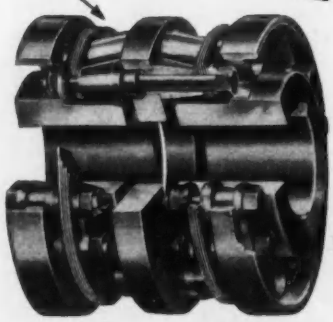

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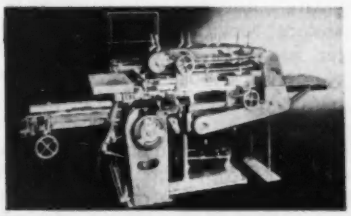

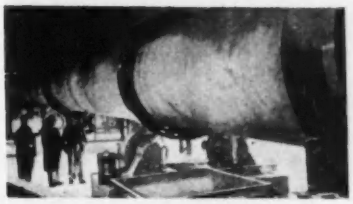

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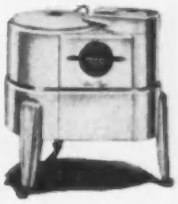
-says AUTOMATIC WASHER COMPANY, Newton, Iowa



"We have used LUBRIPLATE in our washing machine transmissions since 1933. Our laboratory tests as well as field experience indicate that through the use of LUBRIPLATE, we reduced the wear on the gears and prolonged the life of the transmission. The transmission is the heart of any washing machine and the long life and trouble-free performance obtained by the use of LUBRIPLATE in the Automatic Washer transmission has been an important factor in the success of our product."

F. Breckenridge
Executive Vice-President

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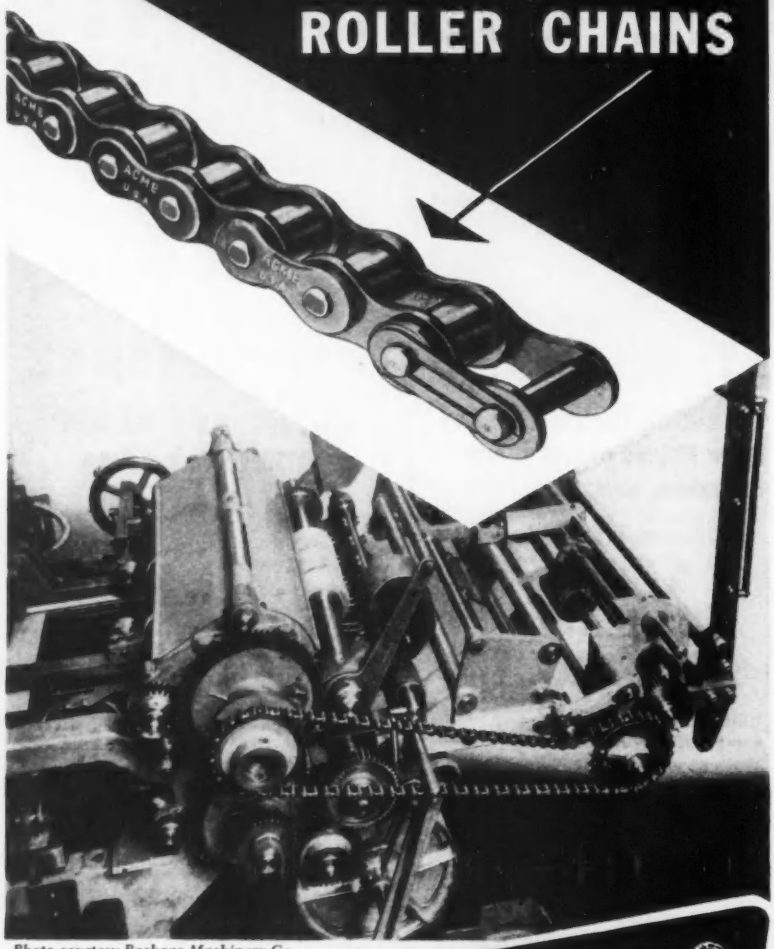

Photo courtesy Package Machinery Co.

ACME is a comparatively new name in chain drive power transmission. Yet, in the brief span of time since this company was founded, ACME chains have been introduced around the world.

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ACME roller chains are designed and engineered to perform each specific job with maximum efficiency and economy. Sprocket ratio, chain impact, tension, drive speed and other factors are determined, not on the drawing board alone, but in the field where ACME engineers observe and test chains at work while new equipment is being designed. In that way, ACME chains are made to meet every test for economy and dependability under all loads at all times.

Your inquiry requesting information or ACME Engineering Assistance is welcomed. Write — or telephone.

engineering students. The second part which includes two-dimensional theory of elasticity, energy theorems, buckling, and miscellaneous topics such as Mohr's circle for three dimensional stress problems was given as a graduate course.

Following the presentation is a selected group of 217 problems to illustrate the principles discussed and their principal application to engineering matters. Answers to all problems have been included for the readers information.

The Copyright Law

HERBERT A. HOWELL, A.B.,LL.B., *formerly Assistant Register of Copyrights, Third Edition.* 6 x 9 *in.*, 376 *pp., Published by The Bureau of National Affairs, Inc., Washington, D. C.*, $7.35.

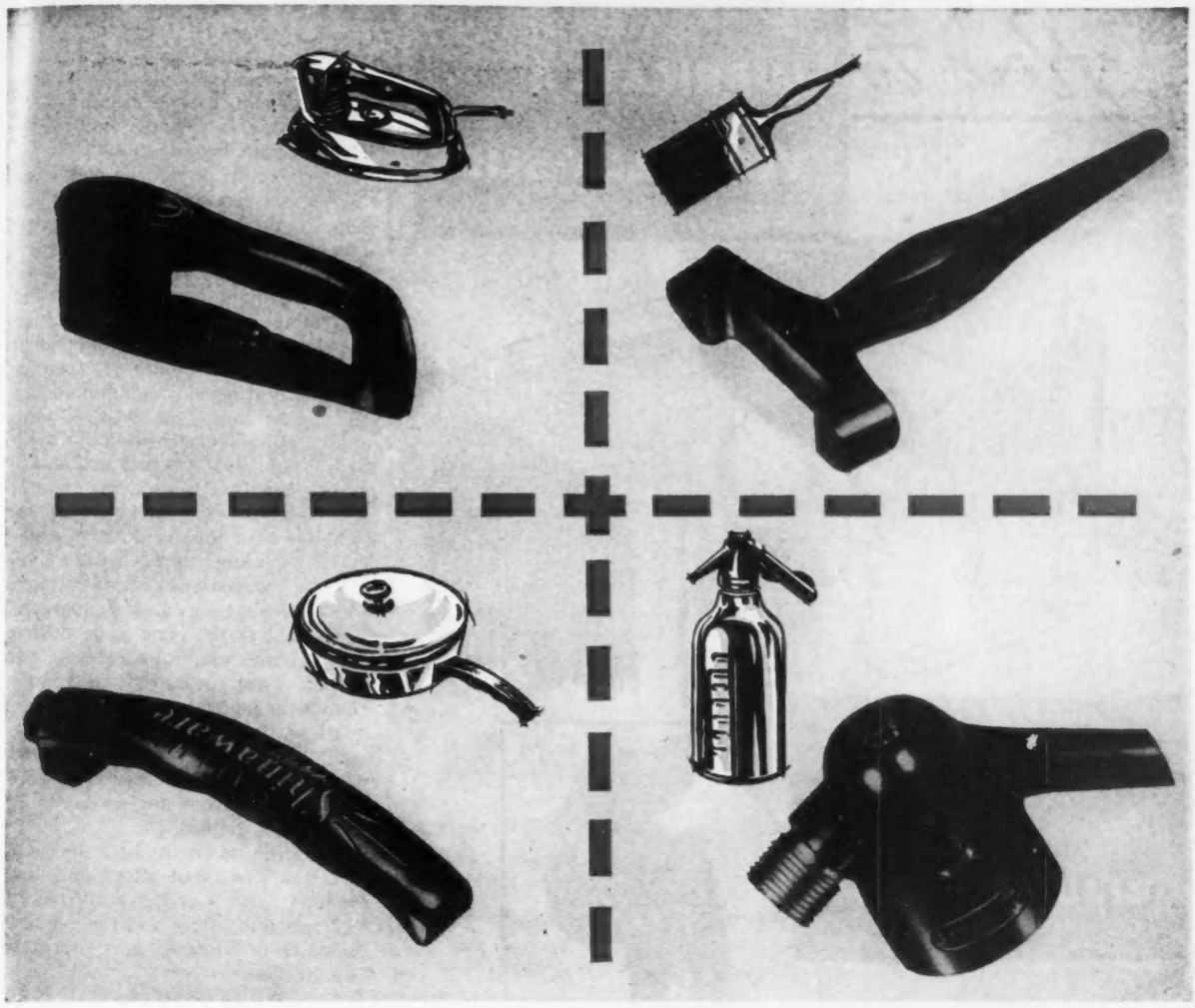
Made up from a series of lectures on copyright delivered by the author to graduate law students, it consists of many of the problems that come up in actual practice. The court decisions referred to have been picked from those made since 1909 when the present copyright act went into effect.

The subject matter of copyrightable material is classified, and discussed at great lengths. Other topics are: commercial prints and labels; non-copyrightable material; who may secure statutory copyright; statutory requisites, form and position of the copyright notice; deposit of copies and registration of works first published; ad interim copyright; statutory requisites for copyright in unpublished works; renewal of copyright; rights secured by copyright, and infringement thereof; remedies for infringement; miscellaneous provisions of copyright act; taxation of copyrights; state copyright laws; international copyright relations; and copyright in territorial possessions of the United States.

Lead In Modern Industry

230 *pp*, 6 x 9 *in. Published by the Lead Industries Association,* 420 *Lexington Ave., New York* 17, *N. Y.* $1.50.

The subject matter of this book is devoted exclusively to the manufacture, applications and properties of lead, its alloys and compounds. It was written to provide the public in general with a broad picture of the whole lead industry and, at the same time, serve as a handy reference source for those who are already using lead and its products. It is sufficiently technical



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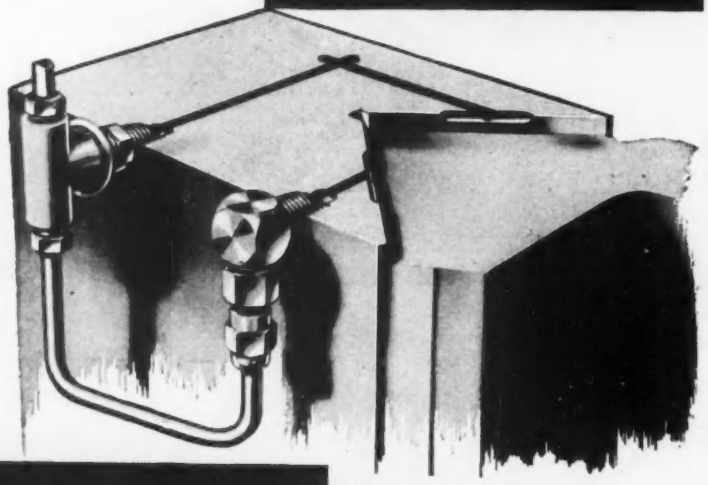
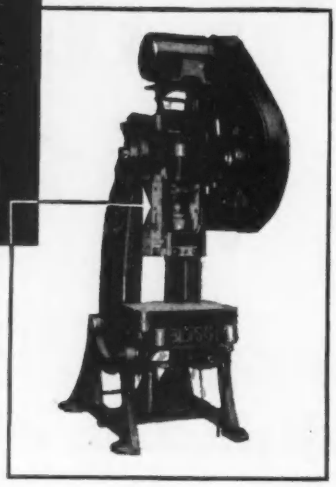


. . . the way BLISS does it with a **BIJUR SYSTEM**



Above cross-section thru gibs of Bliss Inclinable Press No. 218 at point of lubrication, with slide lowered below actual position to show details.

The problem here was to keep a film of oil between the gib and slide contact surfaces. It is solved by drilling thru the gibs to grooves . . . controlling the oil flow thru meter-units at the gibs . . . supplying a measured volume of oil from an automatic lubricator which force-feeds oil to the seven press bearings. This is another example of Bijur "team-work for bearing protection." For aid in solving your lubrication problems, call in a Bijur engineer.

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to be of practical value to the engineer in industry and yet broad enough for those with a more casual interest.

The book is divided into twenty-eight chapters beginning with the history of lead, its production from mine to refined metal, and a detailed description of the various techniques for fabricating the metal into useful form. Separate chapters are devoted to the more important uses for lead including storage batteries, cable sheathing, chemical construction, plumbing, architecture, radiation protection, coatings, solders, bearing metals, ammunition, and so on through a host of other applications. The corrosion resistance of lead and its alloys and methods of using them for chemical construction are fully detailed along with the techniques for joining lead by soldering or welding. Some of the more complex operations are illustrated with both drawings and photographs.

The rest of the book is devoted to the manufacture, applications and properties of industrial lead compounds including white lead, litharge, red lead, tetraethyl lead and others. White lead paints and metal protective paints are covered in detail with actual formulations given for a variety of specific applications.

Included also are the latest specifications for lead, lead alloys and lead products as well as the properties of lead and lead alloys and the physical constants of organic and inorganic lead compounds.

Metallurgy For Engineers

JOHN WULFF, HOWARD F. TAYLOR *and* AMOS J. SHALER, *Dept. of Metallurgy, Massachusetts Institute of Technology.* 624 *pages,* 6 x 9 *in. Published by John Wiley & Sons, Inc.,* 440 *Fourth Ave., New York* 16, *N. Y.* $6.75.

To quote the authors: Metallurgy for Engineers is written to help the reader acquire "an adequate understanding of metals so that he may intelligently select and use them." The first half of the book explains the concepts and principles that underlie metal processing from ingots to finished articles of commerce. The second half deals with the processes themselves. Throughout, the authors write from the engineering viewpoint.

A real attempt has been made to keep the language plain, the illustrations simple, and the ideas lucid. Only those principles are included that are required for understanding the processing of metals into useful articles by casting, welding, or working.

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WHEN ZINC IS BEST SUITED FOR THE JOB —WHY USE SUBSTITUTES?
The fallacies of zinc substitution programs under the guise of "conservation" are brought to light in the new pamphlet "More Facts About Zinc" just issued by the American Zinc Institute, Inc.
ask us for a copy
ZINC IS IN GOOD SUPPLY AND YOU CAN DESIGN WITH FULL CONFIDENCE THAT THE METAL WILL BE AVAILABLE WHEN YOU NEED IT!

NO REASONABLE SUBSTITUTE FOR ZINC DIE CASTINGS

These ZINC Die Castings are the principal assembly components of the new four-jet automobile carburetor pictured below. By no other means of manufacture can such amazingly complex parts be produced at anything approaching comparable cost. After simple trimming operations, only the tapping of cored holes and the drilling of additional holes at odd angles are required to prepare these parts for assembly. Die casting is, truly, the shortest distance between raw material and finished part.

This four-jet carburetor is really two carburetors in one. The primary unit alone is in use until unusual acceleration is called for (as when passing a moving car), then the second unit comes into play.

While a carburetor bowl may be an extreme example of castability, it is an established fact that the physical and economic advantages of ZINC Die Castings are such that other materials and manufacturing methods seldom can be substituted. *With ample supplies of Special High Grade zinc assured, and with die casting equipment readily available, product engineers should continue to take advantage of the economies of ZINC Die Castings.*

If you are not now using ZINC Die Castings in your products, you may be overlooking a practical means of materially lowering your costs. Consult with any commercial die caster—or write to us. Ask for a copy of "Designing for Die Casting."

The New Jersey Zinc Company, 160 Front St., New York 38, N. Y.

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RCA Develops High Frequency Transistors

One serious limitation on the use of semi-conductor transistors has been removed with the announcement by Radio Corporation of America that they have developed a high frequency point contact transistor. This latest discovery opens up new applications for the germanium units that threaten to replace vacuum tubes (PRODUCT ENGINEERING, April 1952, p. 208).

Prior to this development, point contact transistors that consist of a tiny crystal of germanium and fine contact wires, were limited in operation to oscillations in the neighborhood of 50 megacycles per second, and applications were limited to these frequencies. RCA's new transistors were made to oscillate at frequencies well up in the 100-to-200 megacycle band, so that new uses in ultra-high frequency television. FM radio, and point-to-point radio communications are now possible.

Studies have indicated that the spacing between contacts of the transistor is the most important consideration in developing units for high frequency work. Tests have indicated that the closer the spacing, the higher the frequency at which the transistor will oscillate.

Further tests have indicated that the resistivity of the germanium crystal is also a factor in establishing frequency response and stability. By using different combinations of spacing and resistivity, RCA transistor engineers were able to develop a complete range of high frequency units that oscillated with good stability up to 225 megacycles per second.

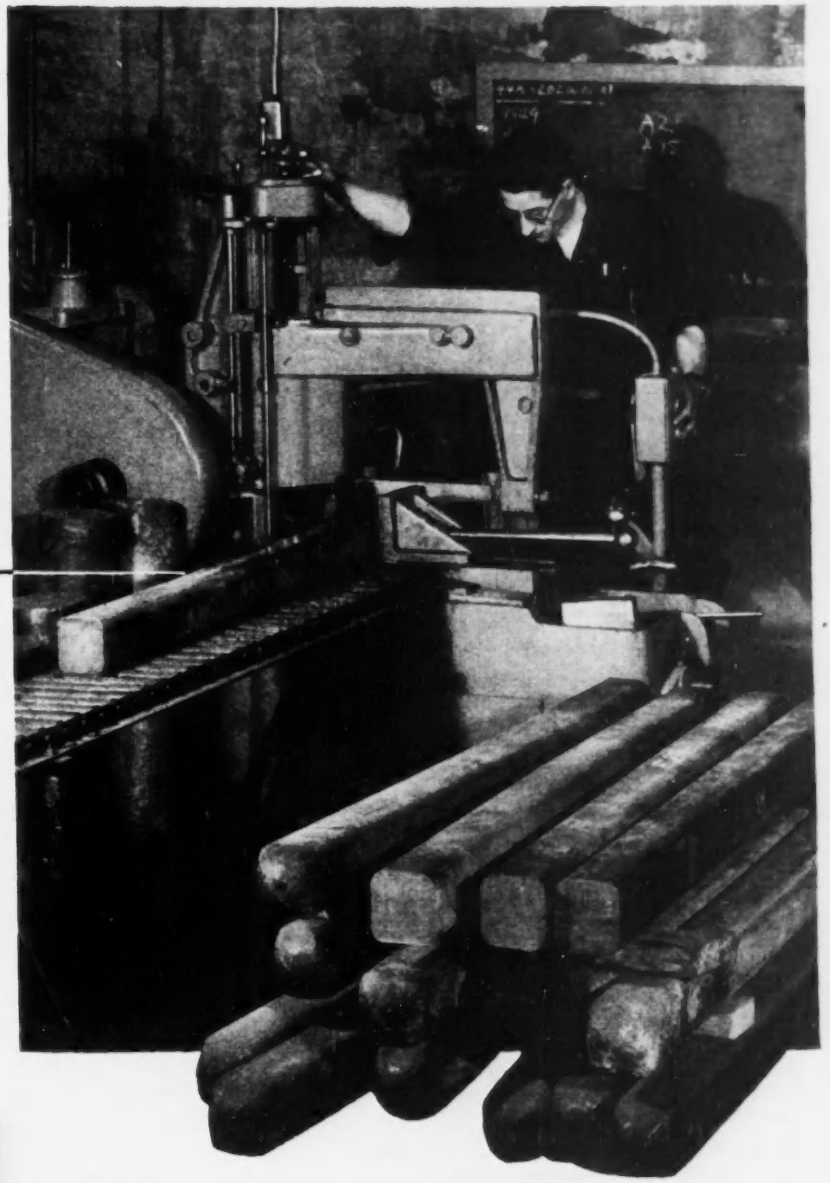
New Film for Ultra-High Speed Photography

WITH A TOTAL "RED SPEED" faster than any other material on the market, a new infrared-sensitive motion picture film developed by the Eastman Kodak Co. permits the taking of motion pictures in the dark with infrared illumination, or in the semi-dark without. While they originally developed the film for spectographic work, Kodak now recommends it for ultra-high speed photography as well. since it does not require additional lighting because of its sensitivity to the infrared range of the spectrum.

To test the speed of the film, University of Rochester scientists made successful motion pictures of an audience in a theatre when the house lights were dimmed to 1/70th of normal room illumination.

Since Kodak will not process this

Serving up TONS of Vacuum Melted Metals



Preparing samples of vacuum melted metals for analysis.

PRODUCTION on vacuum melted metals that was formerly measured in pounds can now be measured in tons. Vacuum Metals' new expanded facilities are capable of producing 5 tons per day of Gas Free High Purity metals and alloys.

Vacuum melting techniques provide metals of higher purity . . . and alloys held to closer composition tolerances than ever before achieved commercially.

The unusual physical, chemical and electrical properties of these metals have proved of particular value for applications such as electronic and electrical parts, magnetic materials, bearing materials, diaphragms, instrument components, and Atomic Energy projects.

Metals now being vacuum melted include copper, nickel, iron, and molybdenum. Further information will be furnished gladly on request.

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SPECIAL ALLOYS
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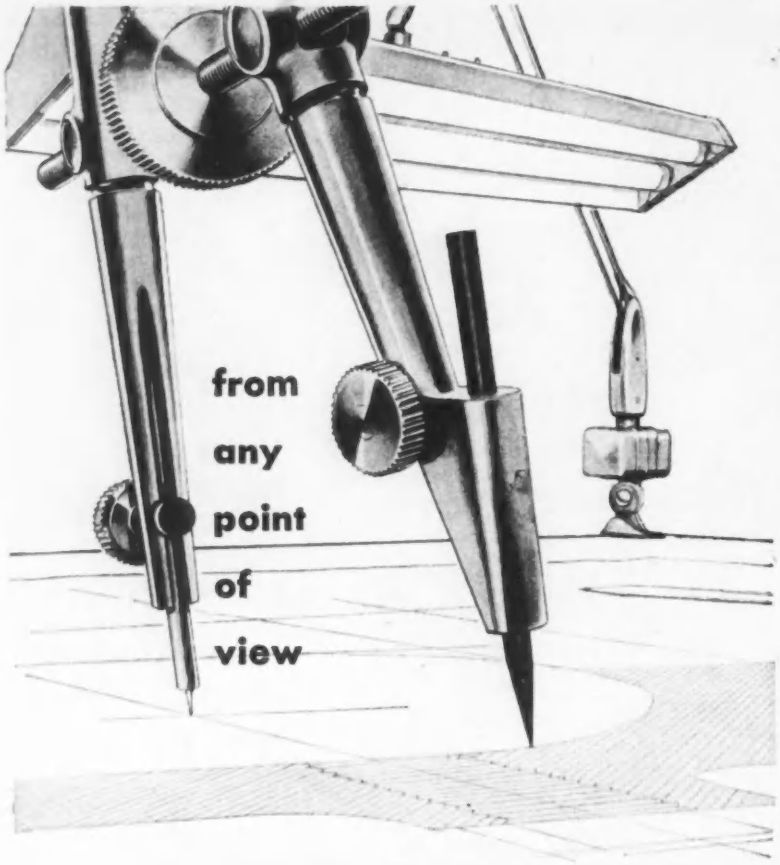

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film, the company recommends that users develop pictures for from 4-8 min in Kodak developer D-10. This produces a photographic negative that must be printed on another piece of film to produce a positive print for projection purposes.

Called Kodak Spectroscopic I-N Film, it can be used in any standard 16 or 35 mm motion picture camera accepting roll film or magazines, and is supplied in 100 ft lengths. But it will not be made available in 35 mm cassette loadings for still cameras.

Engineers to Meet At Chicago's Centennial Of Engineering

OVER 30,000 CIVILIAN ENGINEERS from the United States, Canada, and Europe will meet in Chicago this month for a conclave celebrating the 100th anniversary of the founding of the first national engineering society in the United States, the American Society of Civil Engineers. Over 51 American engineering organizations and nine foreign societies will participate in the meeting which will start on September 3rd and run until the 13th.

Many of these groups plan technical meetings of their own in this period. The anniversary program consists of 12 sections, all tied to the Centennial theme, "Human Well-being Through Engineered Progress."

In addition to the meeting program, there will be an engineering exhibit and a dramatic stage presentation illustrating engineering progress through the past 100 years.

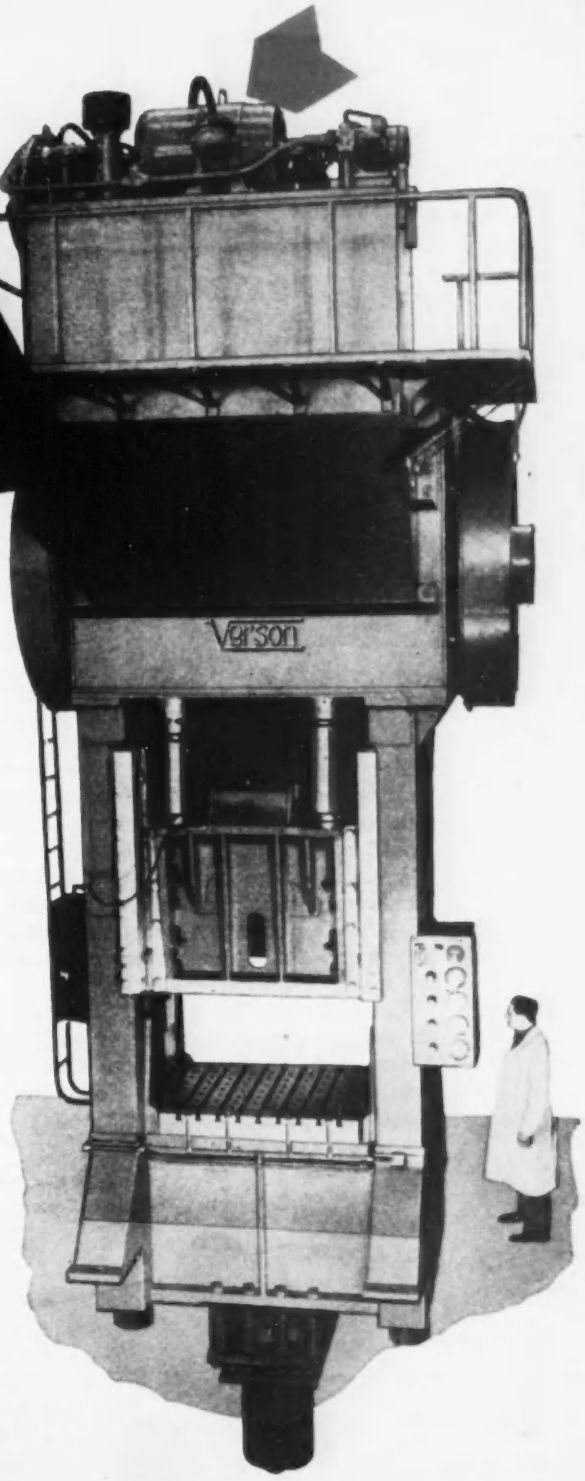
Active Rudder Turns Ship On Its Own Axis

HAMBURG — Pleuger & Company, Hamburg-Wandsbek, have revealed details of their newly developed "Active Rudder" (PRODUCT ENGINEERING, May 1952) that can actively steer and turn a ship while in a "rest" position. When the rudder is turned by more than 60 deg, the ship turns on its own axis.

Key to this maneuver (which has been envisioned by sea-faring men for hundreds of years) is a reversible screw placed on the rudder. A polyphase waterproof commutator motor drives this screw and is housed in a streamlined gondola that is part of the rudder shaft.

In actual tests on a ship, the new rudder has demonstrated a marked improvement in maneuverability. On

Machine with a POWERHOUSE PUNCH!



In one mighty blow, this giant 850-ton, double-action, deep-drawing Verson Allsteel press forms an intricate automobile part.

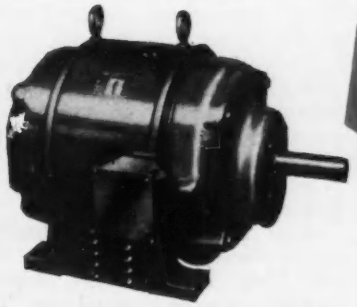
Multiply this by seven strokes a minute, 3 shifts a day, seven days a week and you have a rugged operating schedule . . . one which the Howell motors that power this fine press take right in stride.

Howell engineers worked closely with this manufacturer to select the *right* motor for each job. The main drive motor is a Howell 50 H.P. high slip, high torque motor designed specially for punch press work. The self-adjusting blankholder is driven by a hydraulic pump, powered by a 50 H.P. Howell motor. A 20 H.P. Howell motor operates another hydraulic drive.

Howell will devote the same care and attention to your electric motor problems and needs. With this cooperation and Howell quality, you're assured of motors that will stand up under the heaviest production load over long periods without interruption.

May we help you?

HOWELL ELECTRIC MOTORS COMPANY
Howell, Michigan



Howell Type F Motor. A high slip, high torque motor designed for punching and shearing operations. Sizes ½ to 200 H.P. in open frames; ½ to 125 H.P. in enclosed frames.

HOWELL Red Band MOTORS

HOWELL MOTORS

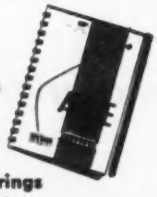
HOWELL ELECTRIC MOTORS CO., HOWELL, MICH.

Precision-built industrial motors since 1915

● The little water meter in your cellar puts hard rubber to the most exacting test a material can get. The disc piston, for example: It spends 10 – even 20 – years under water, and oscillates through a dozen cycles for every glass of water. Machined as precise as 0.0005", it must neither warp, swell, nor wear, or the meter's accuracy would be lost.

Some discs are blanked from Ace Hard Rubber sheet; others start as moldings with metal cores. Moisture absorption is as low as 0.04%, tensile strength as high as 10,000 psi. Special high-temperature compounds safely handle hot water.

There are Ace Hard Rubber compounds that are ideal for many of your mechanical and electrical parts too. Always consult your Ace Handbook when selecting materials – rubber or plastics – for today's production and tomorrow's plans.



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HINTS FOR PRODUCTION-MINDED ENGINEERS

- Meter bearings cut from tubes
- Disc molded over metal core
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- Meter turbine wheel, molded and machined

American Hard Rubber Company

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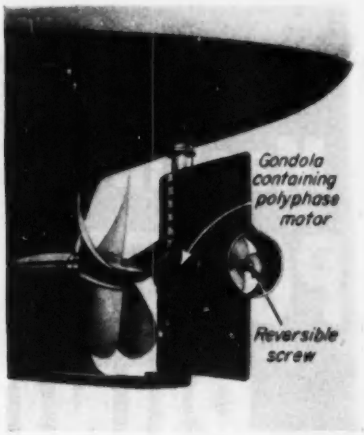


REVERSIBLE SCREW built into ship's rudder is the key to the operation of Pleuger and Company's "Active Rudder." The streamlined gondola contains a motor to drive the screw.

conventional ships, the rudder must be moved by 20 to 30 deg to hold course in heavy seas; the active rudder requires only a two degree movement to keep the ship on course. This factor has considerable economic importance since it reduces loss of forward motion in high seas.

The rudder has also been tested in maneuvers where a ship has to be "backed up"; under such conditions, speed and ease of moving the ship astern have been greatly increased.

Vapor Quick-Dries Paints Chemically

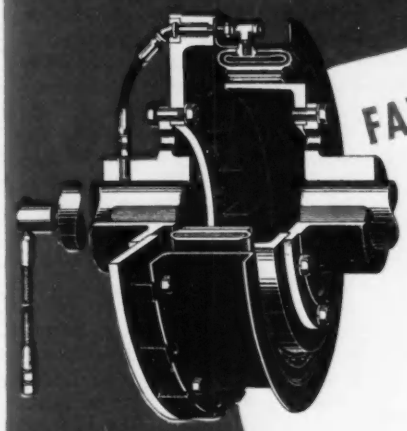
SCIENTISTS AT THE ARMOUR RESEARCH FOUNDATION of the Illinois Institute of Technology have developed a new process called "chem-dry" that dries paints, inks and varnishes in seconds by vapor instead of by heat.

In the new technique, coated materials are transported through an atmosphere of sulphur dichloride in an enclosed drying chamber. The vapor reacts with pigment oils and dries the coating within 20 seconds.

According to the researchers, the drying period ranges from two to 20 seconds, depending on the type of paint, ink or varnish used and the material it covers (which may be paper, cloth, metal, wood, glass or plastic).

After treatment in the chamber, coated materials are dust and tack free. They can be handled, stacked, packaged or given a second coat. The new process, which does not damage paper or many other coated materials if properly purged, speeds up production and releases plant space.

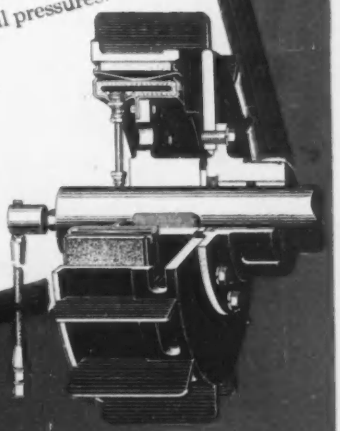
Simplify YOUR POWER TRANSMISSION PROBLEMS WITH FAWICK CLUTCHES & BRAKES



Fawick Type CB Airflex Clutch Application with Ventilated Adapter

FAWICK CLUTCH & BRAKE FEATURES

- **drum-type air operation.** Fawick clutch and brake units provide a 360° friction surface; uniform friction pressure, and constant-velocity contact between the full width of the friction shoes and the drum. Greatest operating torque results from application of the operating pressure at maximum diameter.
- **self-adjusting.** The rugged Fawick actuating tube automatically compensates for wear of friction shoes. This insures complete engagement and dependable service from Fawick clutches and brakes without necessity for any mechanical adjustment.
- **cushioned action.** The actuating tube reduces shaft vibrations, compensates for accidental misalignment, absorbs operating shocks and variable axial pressures.
- **low maintenance.** Fawick design and construction eliminate the problem of clutch or brake lubrication. Uniform friction-shoe wear reduces lost production time for maintenance.



Fawick Type E Air-Step Slip Clutch with Ventilated Drum

For further information on Fawick Industrial Clutch and Brake Units, write to the Main Office, Cleveland, Ohio, for Bulletin ML-22.

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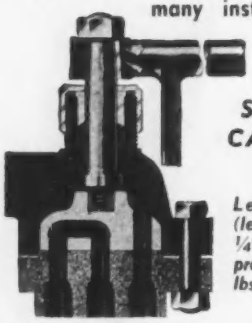
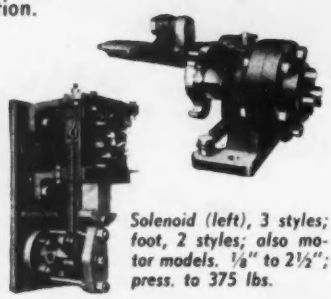
Nicholson control valves were recently adopted as standard by a well-known rubber company, after years of trying practically all makes. Their capacity for longer leak-free service is confirmed by many installation records which show Nicholson valves actually become tighter with use. This is because their non-corrosive flat discs tend to lap themselves on the seats. For all mediums and types of operation.



Send for CATALOG 552

Lever models (left); 4 styles; ¼" to 2½"; press. to 5000 lbs.



Solenoid (left), 3 styles; foot, 2 styles; also motor models. ⅛" to 2½"; press. to 375 lbs.

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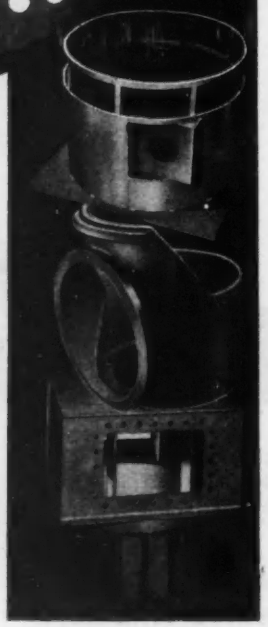

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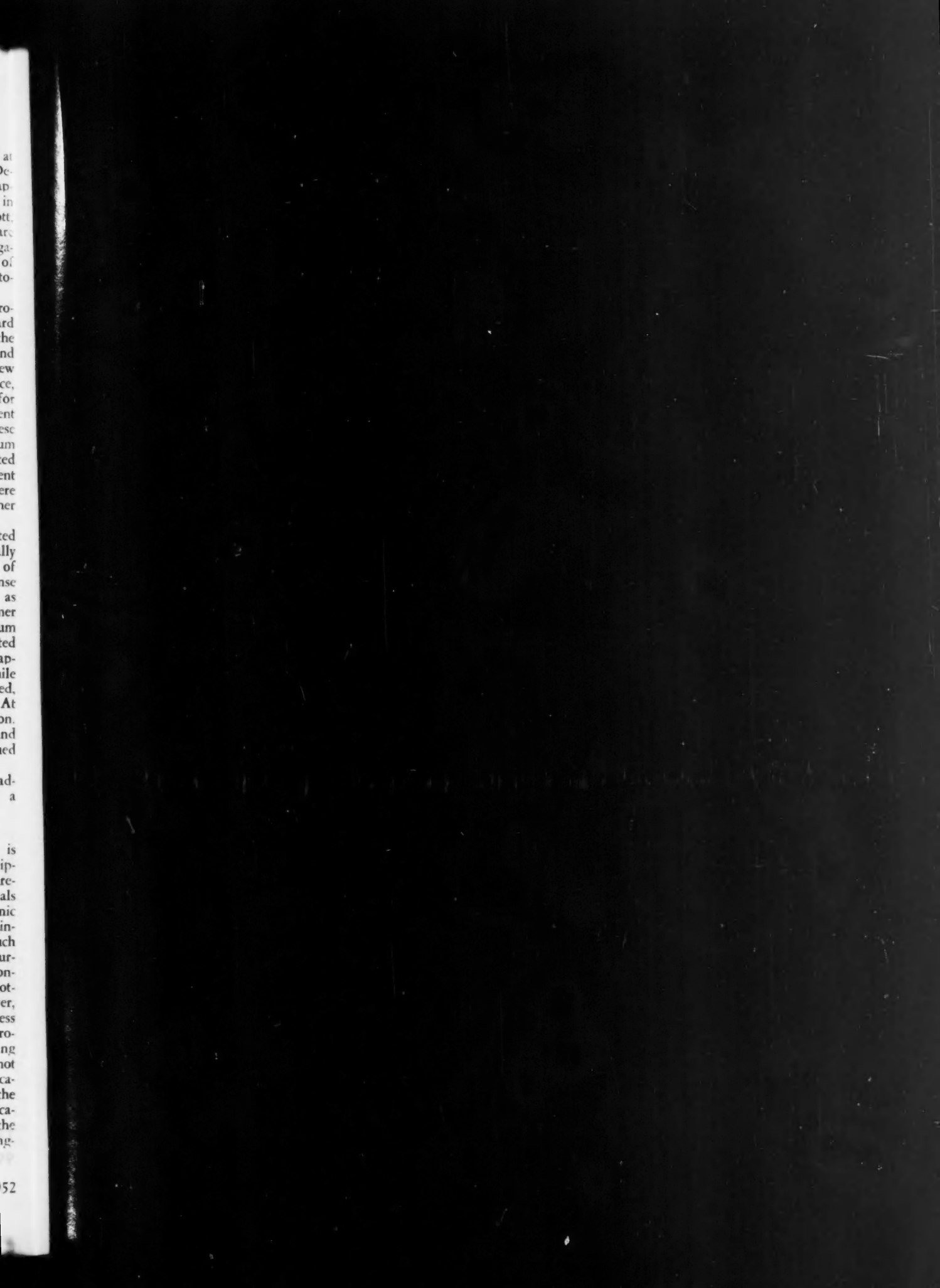
High Vacuum Techniques Improve Adhesion of Evaporated Coatings

FT. BELVOIR, VA.—Studies made at the Army Engineer Research and Development Labs have led to new applications for coatings deposited in high vacua, according to Noel Scott, ERDL physicist. The techniques are being used in experimental investigation of the mechanisms of adhesion of evaporated coatings, and of glass-to-metal seals.

Some metals are difficult to electroplate or solder because natural hard tenacious oxide coatings hamper the formation of metallic bonds. And when these coatings are removed new oxides are immediately formed. Hence, it is desirable to use these oxides for securing adhesion to their parent metals. Excellent adhesion to these oxides can be obtained by high vacuum evaporation techniques. Evaporated films of metals that form hard adherent oxide coatings can be used to adhere tenaciously to their own and other oxides, including glass.

In order to coat oxide-protected metals with a metal that normally shows poor adhesion, the vapors of the two metals are caused to condense simultaneously in such a manner as to produce a transition from the former to the latter. Thus, to coat titanium with copper, titanium is evaporated until the first sign of deposition appears on the titanium surface. While the titanium is still being evaporated, the evaporation to copper is begun. At the first sign of copper decomposition, the titanium source is turned off and the evaporation of copper is continued until no titanium shows.

Transition layers for increasing adhesion can be readily applied in a continuous coat.

U. S. NAVY BUREAU OF SHIPS is working to simplify electronic equipment used on naval ships. As a result, the Bureau is soliciting proposals from civilian contractors for electronic equipment that will be easy to maintain and simple in operation. Such proposals are desired at anytime during the performance of existing contracts and will be evaluated on a "not-to-delay production" basis. However, changes should not be made unless authorized by formal contract. Proposals should set forth any existing specification requirements that cannot be fully met and recommend specification changes that will accomplish the proposed simplification. Simplification proposals should be sent to the Bureau of Ships, Code 810, Washington 25, D. C.

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